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TIME (Msec)
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SIGMA DRACONIS III: VOLCANIC
HOSTILE DIAMETER: 12,104KM
GRAVITY 0.9036 PLANET AGE:
500 MILLION YEARS
ATMOSPHERE: CARBON DIOXIDE
METHANE SULPHURIC ACID
SURFACE FEATURES: VOLCANIC
TEMPERATURE: 900 FAHRENHEIT
MOONS: FIVE PLANETARY
ENVIRONMENT: VERY HOSTILE
CHANCE OF SURVIVAL:
BLEAK...VERY BLEAK

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OUTPOST

THE OFFICIAL STRATEGY GUIDE

Bruce Balfour

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Library of Congress Card Number: 93-087075

ISBN: 1-55958-508-0

Printed in the United States of America

94 95 96 97 CWO 10 9 8 7 6 5 4

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Preface

Men respect books—especially when walloped over the head with them.

Judge Roy Bean

I'm sure it will come as no surprise to my project team, but I've always wondered what it would be like to rule my own planet. With the help of Sierra On-Line and a talented team of extraterrestrials, I'm able to do that now with *Outpost*. With the help of Prima Publishing, I was able to write this book to explain all the underlying science and the strategy aspects of *Outpost*. Life is good.

You don't need to understand the science behind the simulation to play the game, but it will enhance your playing experience. This game is as realistic as we could make it; as the game manual was limited in size, this book may help you uncover depths in the game that you didn't realize existed. NASA has been kind enough to do lots of research for me during the last 40 years, although they may not have been aware of the real reason they were doing it at the time. This book will give you a look into all that research, as well as the work done by others.

Your purchase of this book will give you the knowledge to save human civilization, just as your purchase of the game has given you the tool to save it. Sure, that's just a side benefit to playing the game, but millions of lives appreciate your purchases. It's a big responsibility, but you seem capable of meeting the challenge. If you don't save humanity, who will? That weird guy down the street? The one who wears the snowshoes all the time? I don't think so.

Designing computer games is an odd business. People are always saying they want my job because their current jobs require them to be responsible people doing productive work, whereas my job just requires a clever idea before I sit back and watch the money roll in. This kind of remark really wallops my weasel. Although computer gamers see only the end product of my work, they don't realize how much time is spent doing research before I finally sit back and watch the money roll in. And what am I supposed to do with all the money? They bring it in dump trucks, wheelbarrows, dogsleds, or anything else they can find, then back up to my front door and dump it in a pile so large that I have to burn my way out. Believe me, it's not an easy life.

If you've thought about colonizing space, but you didn't know how, maybe this book and the game will give you a few ideas. The bibliography at the back of this book will provide you with a wide range of information sources. Read the books, think about what they have to say, then make it happen. National governments that think further into the future seem to have an edge on us right now. Private groups and corporations are limited by their funding. The *Outpost* team is busy on their next project. Someone has to build humanity's future in space, so it might as well be you.

Remember to write home when you get there.

Acknowledgments

I started working on this book in the late 1950s…or at least it feels that way. There are a number of people I'd like to thank for putting up with me while I was rushing around working on this book, managing a team of deranged psychotics, and testing the game. Because these are also the only people who will read the acknowledgments, this is a great time saver instead of writing each one of them a thank you note.

First, I have to thank my development team at Sierra On-Line, the Extraterrestrials from Sigma Draconis III: Dan Brotherton, Jon Bock, Randy MacNeill, Rich Powell, and Michael Lytton. Their fine work and dedication to the project made most of my hair fall out during development, but it has since grown back.

Second, I have to thank my former branch chief at NASA-Ames Research Center, Dr. Henry Lum, a brilliant scientist who got me involved in a variety of marvelous projects and showed me what a good manager can accomplish. I'd also like to thank the late Dr. Skip Nunamaker, who managed the Space Sciences Division while I worked there, and recounted the great story about transporting the diamond windows for *Pioneer Venus*.

Next, I'd like to thank Dr. Louis Friedman of The Planetary Society for his comments and suggestions, as well as his organization's efforts toward international space cooperation and keeping the American space program alive.

At Sierra On-Line, there were a number of people who aided and abetted in the development and marketing of *Outpost*, without whom the game might still be a secret: Jim Thomas, Mark Hood, Stuart Moulder, Dan Carver, Bill Linn, and Dan Rogers. I'd also like to thank Ken Williams for approving the proposal in the first place, allowing us to plunge into the strategy game market. Additional thanks go to Greg Tomko-Pavia, another former space guy from the Jet Propulsion Laboratory, whom we consulted for interstellar spacecraft design and lots of exotic math stuff. I'm still trying to figure out some of those formulas he gave me.

At *Computer Gaming World*, I'd like to thank Johnny Wilson, Russell Sipe, and Martin Cirulis for their kind reviews and reports about *Outpost*. I'd also like to thank them in print for that 1989 Adventure Game of the Year award for *Neuromancer*. These guys are tough critics, so I really appreciate their support.

At Prima Publishing, I have to thank Roger Stewart for taking several years off my life by asking me to get this book finished soon enough to release it at the same time as the game. Okay, he didn't have to use a very big gun to make me do it, but this sounds more dramatic. I also have to thank Dan Foster, Ron Resnick, and Diane Pasquetti for their support.

My literary agent, Don Maass, deserves special thanks for all the wrestling, punching, knife-fighting, and hair-pulling required during the contract negotiations. He did all these things to himself, which mystified the publisher and served as a disorienting negotiating tactic that made us all happy with the contract in the end.

Warren and Betty Balfour deserve my thanks because, without them, I wouldn't have written this book...or anything else, for that matter. In fact, I wouldn't even be here. I'd also like to thank Mark Balfour, who prods me along by asking why I'm not on the cover of Ti*me* magazine yet.

Closer to home, I owe a special load of thanks to Leslie Wilson, who helped keep me alive during these dark times. She prods me along by asking why I'm not emperor yet. I'd also like to thank the "little people" for their support, whose names, in this case, are Heather and Hope Wilson. They prod me along for no apparent reason.

Finally, I'd like to thank all the strategy game players who took the time to buy *Outpost* and play it when they could have been doing something meaningful with their lives. Without you, my occupation would not exist.

"Best of show!"
Computer Electronics Show
Game Bytes

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Computer Gaming World

"Absolutely the best science fiction software ever published!"
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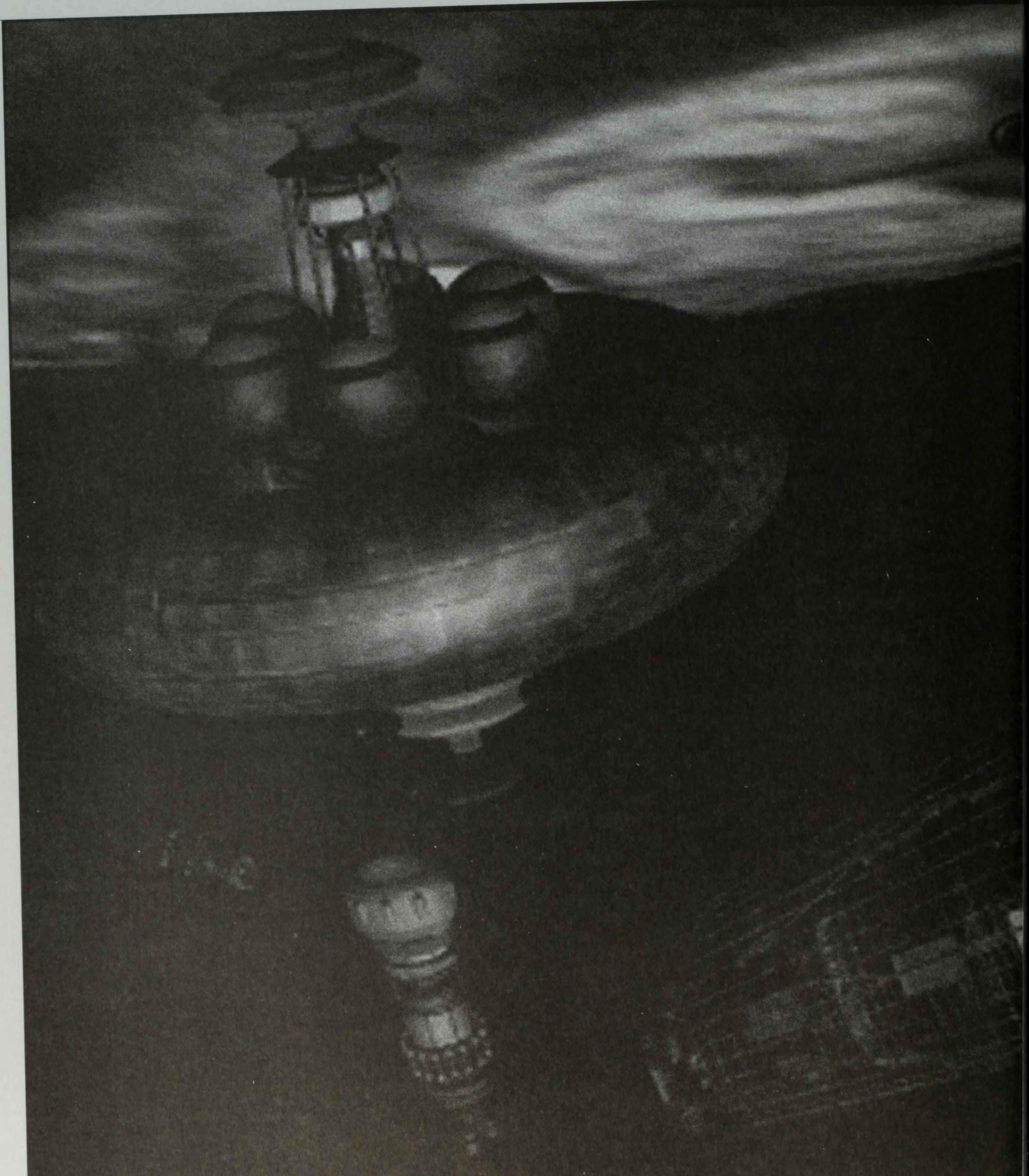


Figure 1-1 Starship fueling at Jupiter

1

Introduction

> *Through the vast reaches of space and time, part of the matter of the universe has evolved into living matter, of which a tiny part is in the form of brains capable of intelligent reasoning. As a result, the universe is now able to reflect upon itself. In this respect, at least, the whole evolutionary chain of events is endowed with meaning.*
>
> Astronomy Survey Committee,
> National Academy of Sciences

Outpost gives you the opportunity to rescue human civilization from certain doom. You have control over a huge number of tiny lives; determining their destinies, forecasting their fates, meddling with their minds, tampering with their technologies, interfering with their...well, you get the idea. Anyway, you assume an awesome responsibility as the natural leader of the last human outpost. It's a tough job, fraught with danger, but you have to do it because nobody else can. This chapter defines the nature of the beast; the what and why of *Outpost* and this book. In time, all will be revealed, but right now we need to outline what lies ahead.

What Is *Outpost*?

Outpost is a strategy simulation in which players explore new worlds, research new technologies, and strive to rebuild human civilization on distant planets. Because it's based on NASA research into future space projects, as well as current planetary science and theories on interstellar spacecraft design, *Outpost* is a realistic simulation of the complexities involved in building a self-contained colony on a hostile planetary surface.

Starting with projections of technology that will be available 50 years from now, you send out probes from Earth to collect data on possible planets orbiting distant stars. While those probes continue their journeys, you will build and stock a colonization starship powered by a nuclear fusion propulsion system. Armed with the data from the probes, you will choose your target star system and launch your mothership on its interstellar voyage.

On arrival at your new home, your job is to survive and establish a colony on the planet's surface. This colony must be managed as if it were a living city: continuing the building program, keeping the population employed and happy, exploring the new environment, mining for resources, recycling waste products, dealing with random events such as meteorite strikes, advancing the civilization, researching new technologies, and establishing long-term terraforming operations on those planets that can retain an atmosphere. You can also develop multiple colonies and establish trade between them.

Because you're in charge, the fate of all those tiny lives will rest in your hands. If you make a lot of bad decisions, you alone will be to blame if the last bastion of humanity fails to survive. If you succeed, you will win the deep and heartfelt gratitude of all those simulated people. And isn't simulated gratitude what life is all about?

Simulating the Future

Outpost is based on fact, but it's also a game, which means that there are bits of humor and the occasional dramatized event that push the envelope in terms of realism. A reasonable amount of scientific progress over the next 50 years is also assumed. However, the underlying model, the technologies, and the science have been extensively researched.

As with any mathematical simulation that operates on a personal computer, the vast complexity of the real world must be reduced to simpler models. Certain details must be implied, rather than calculated. The trick in building a believable simulation is in deciding which factors are important for that particular model. For example, the variety of planets used in the game is based on bodies in our Solar System. A Mars-type planet in *Outpost* is very much like the real Mars, except for individual surface details. The real surface of Mars has been mapped and its features have been identified, but this would have been too much detail for a game of this size, and would have taken some of the discovery element out of the game for those familiar with Mars. However, the environmental elements and planetary statistics are quite similar to the real thing.

One of the challenges with the *Outpost* design has been to make sure the planetary science data are as current as possible. Books on astronomy and planetary science are now out of date almost as fast as they are published. When probes such as the *Voyagers* have encounters with a planet, they send back enormous amounts of data, not all of which can be processed or studied immediately. Earth-based instruments also continue to improve, providing us with more information each year. For example, the November/December 1993 issue of *The Planetary Report* notes that Pluto is covered by surface ices that are 98 percent nitrogen, rather than methane, as previously thought. Carbon monoxide was also detected for the first time. These observations were made in Hawaii with a new instrument on the United Kingdom Infrared Telescope. At the Jet Propulsion Laboratory in Pasadena, California, research by E. Myles Standish concludes that the hypothetical tenth planet of the Solar System does not exist. His analysis is the first to make use of Neptune mass measurements made by *Voyager 2* in 1989, demonstrating that another planet is not required to explain possible variations in the orbits of the outer planets. The accuracy of these measurements shows that the presumed wobbles in the orbits of Uranus and Neptune stemmed from erroneous old observations and calculations.

In any case, much of the planetary information in *Outpost* will probably be out of date a few months after its release. That's just the way the scientific cookie crumbles.

Outpost, like other simulation games, leads a sort of schizophrenic existence in the computer gaming world. On the one hand, it looks and feels like a game: it's fun, amusing, perhaps even addictive. On the other hand, it's a model of a complex system in the real world. Poking the model at one point has an effect on everything else in the model. Events will occur that you can't anticipate. You can build your colony and explore various lines of research without running out of time or being attacked by the Giant Crab People of Fomalhaut Four. Although there are goals in the game that allow you to gauge your progress, you're free to ignore them. Without even noticing, you may learn things from the simulation. This would seem to place *Outpost* in that nebulous game category known as "infotainment." In any case, *Outpost* can be played from a realistic point of view or as a game, whichever holds the most appeal for you.

Why *Outpost* Exists

While designing my first Sierra adventure game, *The Dagger of Amon Ra*, based on one of Roberta Williams's characters, I met Stuart Moulder, who denies being one of Roberta's characters. At that time, Stuart was a Sierra producer with an interest in strategy games. In the dark recesses of his mind, Stuart had a plan to sell our adventure game company on the idea of doing strategy games.

Aware of my background with NASA and computer games, Stuart asked me if I was interested in designing a strategy game dealing with space colonization. After verifying that Stuart was still taking his medication, I worked out a proposal with him. Stuart made a series of midnight phone calls. I arranged bail after the police traced those obscene phone calls back to Stuart's number. When he returned to work, Stuart talked to Ken Williams, who had some reservations about entering the strategy market. A pole-vaulting match was arranged to settle the matter. Stuart won, after we rigged the contest by sawing 12 inches off Ken's pole, and *Outpost* was born.

Soon after that, knowing that he'd given birth to a multiheaded monster that was likely to kill us all, Stuart sneaked out of the building and took a job with another Sierra division, now known as the ImagiNation Network (INN). However, my fate was sealed. I was chained to my desk for 17 months, armed with a project team and a design, and informed that my dog would be held hostage. Once a day, a bowl of moldy cheese puffs and a cold pot of coffee were shoved under my door. The conditions could have been worse, but Ken trusts me. When *Outpost* was finished, I realized I didn't have a dog, but we had a strategy game that was fun to play.

Why This Book Exists

The development of entertainment software takes time and money: too little time and too little money. Once a game is started, it progresses at a breakneck pace so that it will be released before someone else publishes a similar product. In this mad rush to get the game finished, someone is given a limited amount of time to make a few marks on paper with a crayon before it's torn from their hands, copied, and thrown into the box along with the game; this is what's known as The Manual. The documentation writer often has other minor functions on the team, such as game design or programming, which is also known to take time. However, a writer who happens to be fast with a crayon may produce a good manual that adds value to the game.

In other cases, the subject may be too big and the background material too complicated to be covered fully in a game manual. Such is the case with *Outpost*. Planetary science, stellar ecospheres, materials processing: these are all subjects that are best treated in books devoted to these subjects. In this book, these topics are described to the extent that they impact the game, giving you a greater understanding of the simulation and how it works. Of course, many other topics are covered in this book—including strategy, hints, hidden secrets, cooking tips, training your cat to do sit-ups, and the meaning of life—giving you a complete and well-rounded education in the subject of *Outpost*.

Why You're a Smart Person

That much should be obvious. You bought this book.

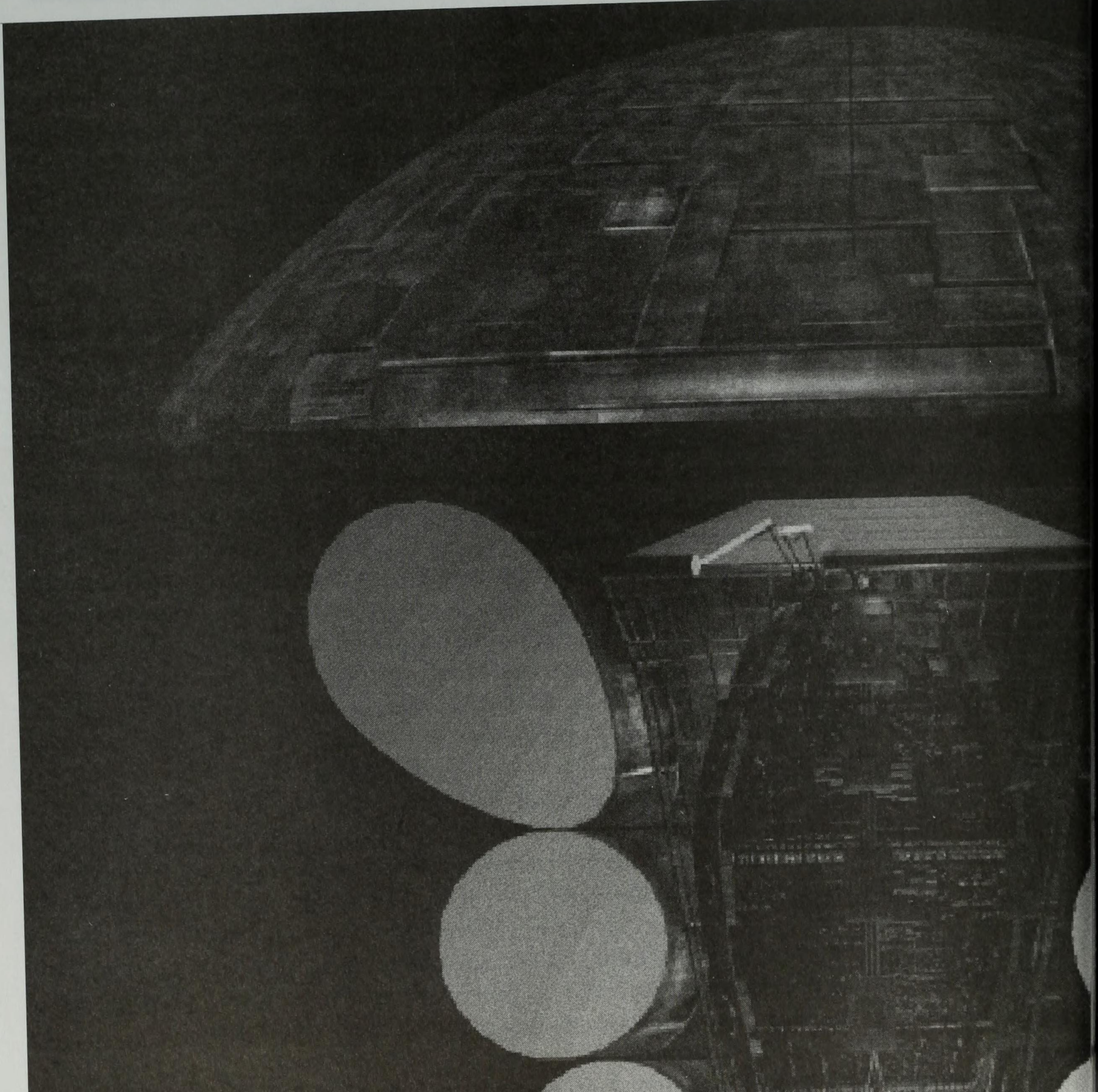
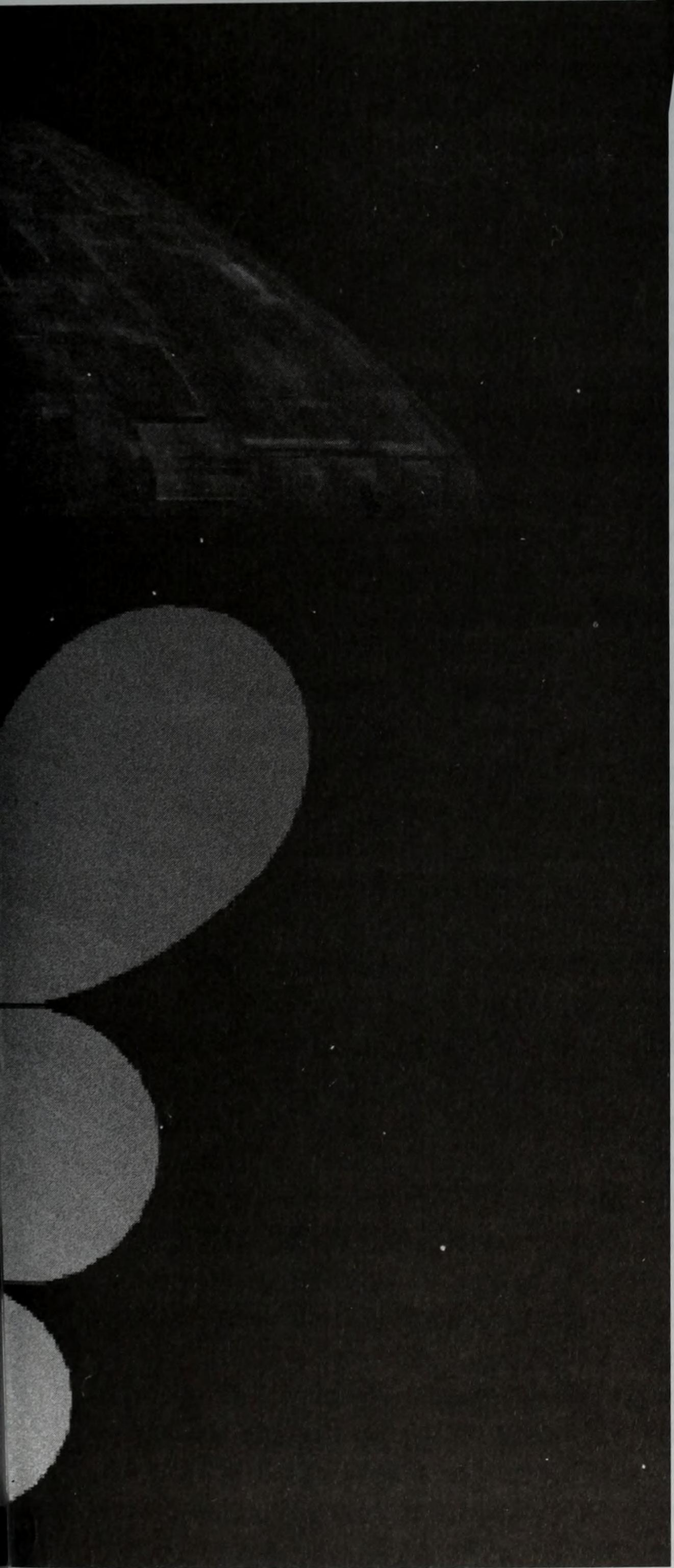


Figure 2-1 Cross-section of starship



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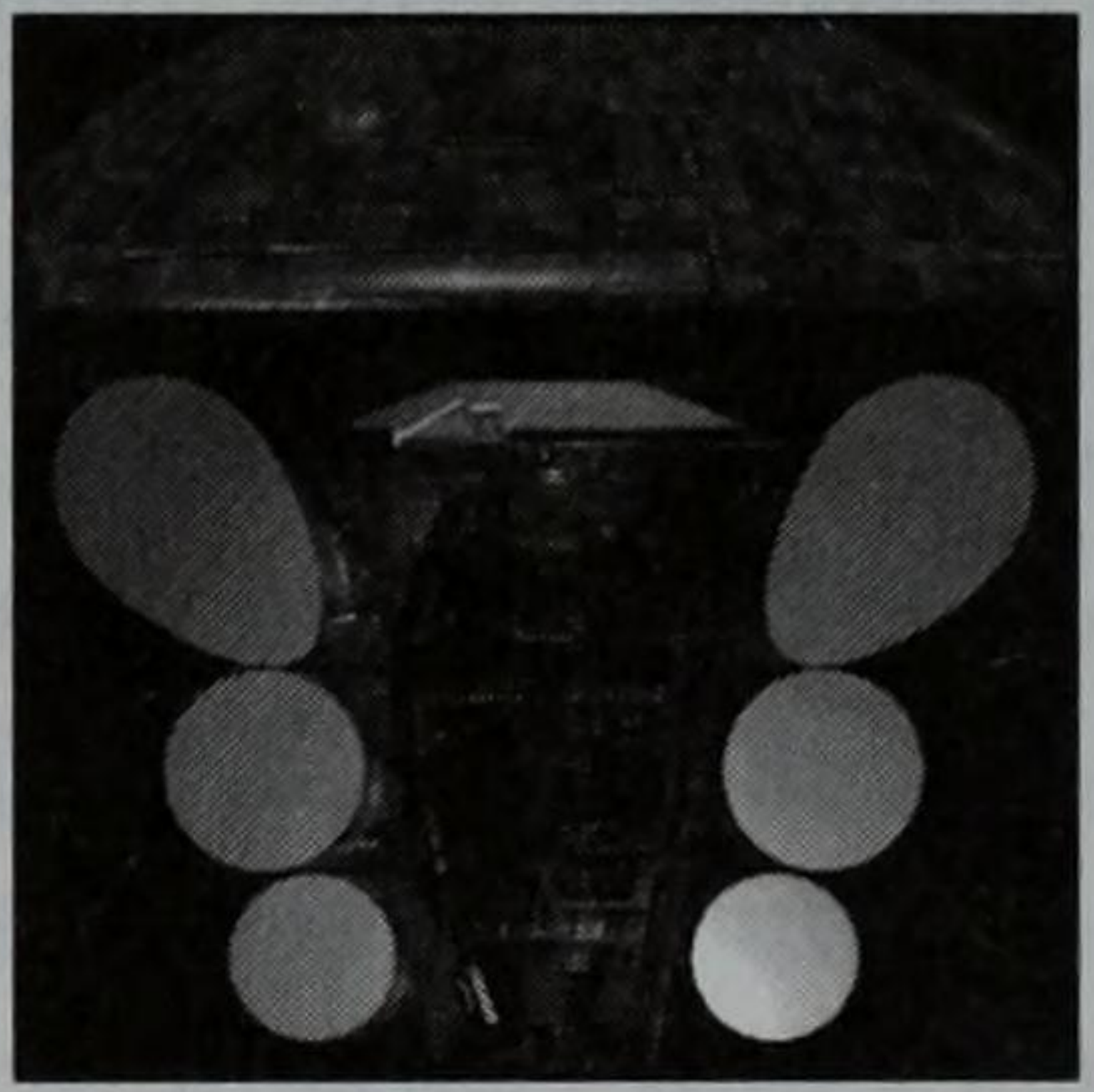


There Goes the Neighborhood

Earth is the cradle of humanity, but one cannot remain in the cradle forever.

Konstantin Tsiolkovsky

This chapter gives you the story behind *Outpost.* Not only will you learn why mankind is forced to abandon the planet of its origin, you'll also learn what the future will be like 50 years from now, understand why objects from space can be such a headache, discover what I think of public apathy toward the space program, and find out who's going to pay for the rescue operation.

Why Leave Earth?

Human life on Earth is about to be destroyed by a big rock.

The space program has limped along since the 1990s, with other nations launching probes and the occasional spacecraft to other planets in the Solar System. Government funding for NASA continues to shrink year by year. Private companies still launch a few satellites, probes, or robot landers, but none of the conglomerates sees any short-term profit potential in space operations, so they have little interest in space-related investments. Public organizations, such as The Planetary Society, continue using their resources to fund small space projects and encourage international cooperation, but cannot afford large-scale operations. This is the situation when mankind becomes aware that it may have made a mistake.

Astronomers observe a dark object approaching the Earth. Although its flight path is similar to that of a previous short-period comet discovery known as Vulcan, the object shows no signs of a cometary tail or coma, causing it to be classified as an asteroid. There is general agreement among astronomers that the asteroid is, in fact, the extinct comet, now covered with insulating dust after so many passes through the warm inner Solar System. The variation in Vulcan's former trajectory is explained by intermittent jets of heated gas from its interior, acting as thruster rockets that make it appear to defy gravitational laws. After someone remembers the titles of some old science fiction novels, the enormous asteroid is renamed Vulcan's Hammer by the media.

Calculations show that the asteroid has an excellent chance of intersecting the Earth's orbit in the year 2045, striking the surface of the planet with a billion megatons' worth of destruction. Many people consider this to be a bad thing.

The media pushes the "end of all life as we know it" story for 2 weeks, but the apparent lack of interest from the short-sighted general public forces most of them to drop the story. The year 2045 is too far away to maintain interest in the subject. The credibility of the story is also weakened by conservative astronomers who emphasize the uncertainty of the asteroid's trajectory. However, one multinational conglomerate chooses to respond to the threat. They begin the design of a colonization starship. There will be time and money enough to build only one.

The starship is to be assembled in Earth orbit, fueled from the atmosphere of Jupiter, then launched on its interstellar voyage. During the starship design stage, long-range space probes will be launched to gather data on star systems with the potential of having terrestrial planets. Faster probes launched during the mothership's fueling will gather more data on the target star system, allowing the colonists to choose their destination planet.

Much too late, one attempt is made to detonate a nuclear explosive near the incoming asteroid. This explosion increases the threat by splitting the asteroid into two pieces that continue on the same flight path as before. The larger chunk is 9 miles across and the smaller piece is 6 miles across.

Projections show that the larger fragment will shatter the Earth's crust for hundreds of miles, bursting upward in an incandescent fireball of vaporized rock, blasting a crater 108 miles in diameter and more than 12 miles deep as the ground moves in enormous waves of liquefied rock. Tsunamis hundreds of feet high will race across the oceans. Heat from the explosion will generate a massive firestorm. A black cloud of dust will rise into the stratosphere, plunging the Earth into its longest night in which land temperatures will fall below freezing and photosynthesis will cease. Nitric oxides will rain from the air, turning the oceans to acid. And that's only the projected damage from the *larger* asteroid fragment.

When the mass hysteria begins on Earth, the space ark is already fueling at Jupiter, loaded with cargo and colonists. The multitudes have realized they're going to die, and they're not happy about it.

Big Rocks Fall from Sky

The dinosaurs lived a happy existence on this planet for 140 million years. Then a big rock fell out of the sky and had a direct impact on their lives. Researchers believe a near-Earth asteroid or comet, about 6 miles in diameter, collided with our world 65 million years ago in the Caribbean basin. This bomb from space wiped out most of the living things on Earth, including the dinosaurs. Those same researchers believe that a similar fate might lay in store for the human race. Only the lowest forms of life, such as cockroaches and insurance salesmen, would have a chance to survive.

Although this topic will be covered in more detail later in this book, it's important to consider the practical aspects of such an impact with the Earth.

First, there will be no chance of resupplying your colonists with shipments from the Earth. Not only are the distances too great, but any survivors on Earth will be fully occupied dealing with their own issues after the asteroid has struck. If you don't produce enough of your own life support resources, and you suddenly run out, your people are going to die. If your colony is starving because you're not producing any food, your people are going to die. The cavalry won't ride in at the last moment to save you, because the cavalry won't exist any more. It's a tough universe out there.

Second, it must be assumed that the colonization ship will contain the only life to survive the global holocaust. If you don't pack the giraffes with your luggage, there will be no more giraffes. If you don't collect the cows, there will be no more cows. If you don't bring the mosquitoes...hey, maybe this isn't such a bad idea after all.

Third, there is no chance to divert this asteroid from its collision course with the Earth. The survey of near-Earth asteroids, and other potential impactors, is such a slow process that it's quite possible to have this sort of surprise visitor from space. There are estimated to be 1,000 to 2,000 objects in Earth's immediate vicinity that are large enough to be a major threat. So far, we've tracked only about 100 of these objects. Judging from cratering evidence on the Earth and Moon, the interval between impacts of objects this size is only hundreds of thousands to a few million years. If they're detected early enough, and they're small enough, and the system is in place to launch an interception mission armed with a nuclear explosive, it might be possible to divert such an object from its intended collision with our planet. At present, this would be difficult, if not impossible. Attempting to divert an incoming object could also make the situation worse by breaking it into pieces or by diverting it to a random location on the Earth's surface.

Smaller objects that strike the Earth with more frequency, perhaps as often as every few decades, are even harder to locate. Estimates vary, but there could be a few million of these objects that cross our path with great regularity. The Tunguska blast, which flattened almost 1,000 miles' worth of Siberian forest in 1908, was one of these small objects: an icy cometary fragment that exploded

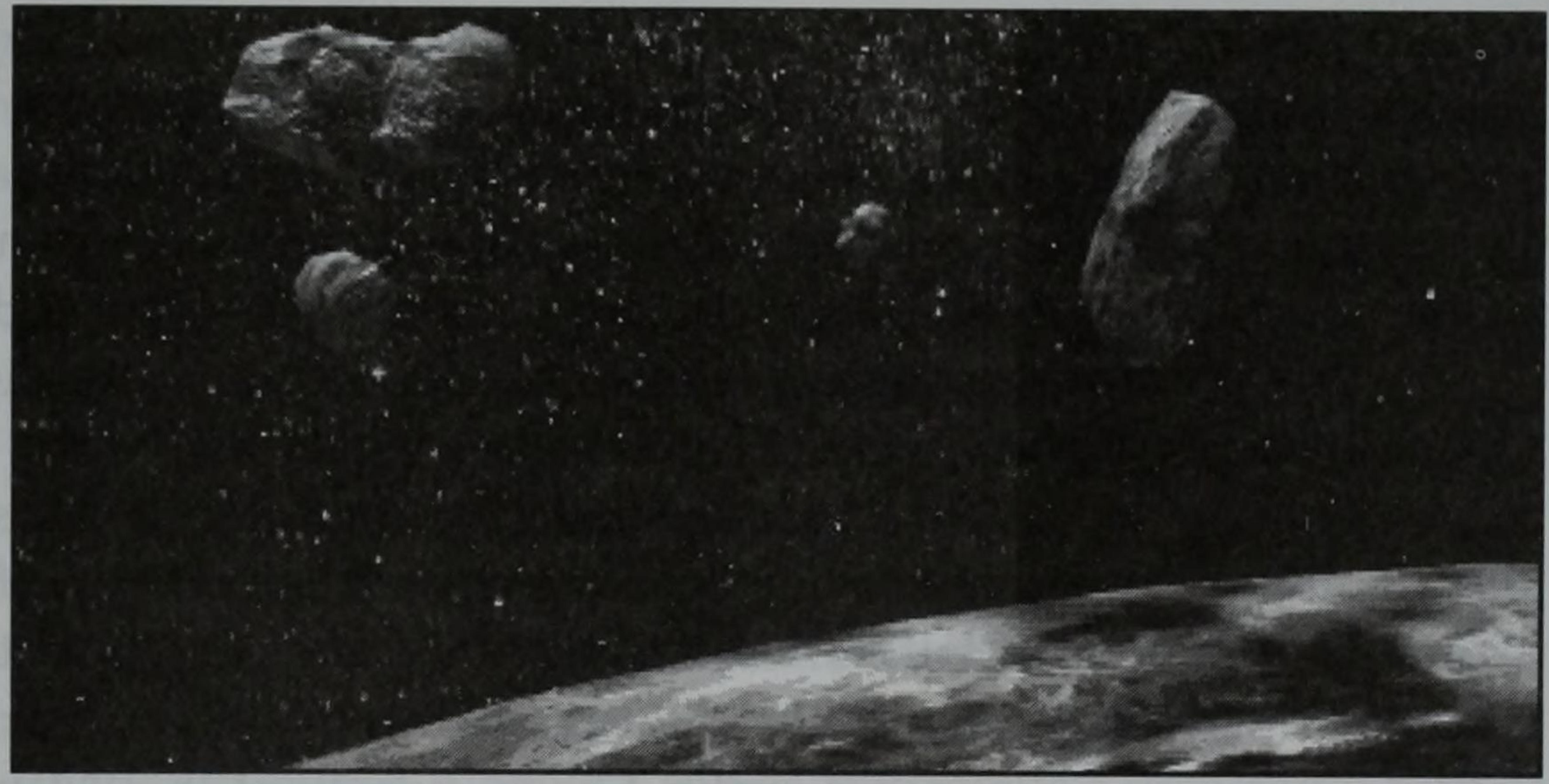


Figure 2-2

Up to 2,000 objects threaten our existence.

before it reached the ground. If a Tunguska-class object were to strike a typical urban portion of the United States, 300,000 people or more could be killed, with property damage exceeding $280 billion. All this damage could be generated by an object less than 200 feet across.

Who's Going to Pay for All This?

Even 50 years from now, there are only two entities that could support an interstellar colonization effort: national governments and multinational conglomerates. In the case of government support, a tremendous amount of cooperation and coordination would be required to engineer such a massive effort, especially if it needed to happen in a short period of time. The staggering sums of money required for funding would be certain to meet resistance from policymakers and members of the public who would not understand the situation. Over a period of years, graduated funding might become available to design, research, and build a colonization starship. The recent problems with gaining approval and money for the American space station serve as an example of the time and effort required to plow through so many layers of government bureaucracy. It's also possible that politicians would not perceive the impending destruction of civilization from an incoming asteroid as much of a threat, especially if it was due to arrive in an election year.

Many big businesses have the same bureaucratic problems as big governments, but this is not always the case. Multinational conglomerates have vast amounts of money at their disposal, and often have the capability of moving those funds where they're most needed, otherwise they'd be out of business. If a business has a visionary leader with the ability to make unpopular decisions palatable to the stockholders, that leader can engage in the luxury of long-range planning. If that leader believes the scientists when they say the Earth is doomed, and if the resources are already available to the conglomerate, that leader could create a colonization effort to save a small portion of the population. Curiously enough, that's the exact situation in *Outpost*.

As a back-up plan, that leader tells the skeptical stockholders that an outpost colony could become a profitable enterprise if the Earth survives. The board of directors is split on the decision, pointing out that the astronomers won't agree on the certainty of the asteroid strike. Others point out that Mars is a closer planet to colonize. Still others point out that some astronomers have speculated on the possibility of Earth having a perturbed orbit after the impact that could affect other local planets. A compromise is reached. The initial proposal called for the construction of four colonization starships to journey in pairs to two different star systems. Only one starship receives approval, reducing the impact on the corporate budget if the Earth should survive.

The conglomerate provides the budget; you provide the brains. Humanity needs you to save them from themselves; you must lead them out of the darkness into the light of a distant star.

Why Can't Aunt Phoebe Go Too?

The human population of the colonization starship is limited to 200 people, most of whom are scientists with the required skills to rebuild civilization. The ship also carries a tremendous amount of cargo. The main limitations to the colonization effort are the ship's propulsion system and the funds required to build the starship. The departure mass of the starship, powered by fusion technology and fueled with hydrogen from the atmosphere of Jupiter, is almost all fuel. There are no gas stations available on this journey. The additional mass of the human cargo and supplies is just dead weight until the ship reaches its destination. Because there is no propulsion system that is 100 percent efficient, that payload is limited to a small portion of the weight that can be moved by the vehicle. Of all the possible people that could be rescued, the decision must be weighted toward which 200 people will best serve the future of the human race. The supplies that go with them are the minimum necessary to support the colonists.

There's One in Every Crowd

Try as you might, there's always going to be someone in a crowd who thinks you're an idiot. This is also true among the colonist population. Fifty years is a long time to spend in space, even if you spend most of that time asleep. People start wondering what it would be like to be in control; or who elected you to be in charge. It would be nice to travel with 200 happy people whose only ambition is to follow your orders, but this is a simulation of reality. This happy fantasy isn't going to happen.

A second leader rises up among the colonist population. During the arrival phase of the mission, the rebel leader may gather up to half of your crew and resources, then sneak off with them as a thief in the night. Needless to say, this can be a disturbing turn of events. However, you are not colonizing another planet with the intent of making war on your own people. Let them start another colony. Perhaps if your colony fails, the rebel group will survive to create a new home for humanity.

When the colonies reach a certain level of self-sufficiency, the option to establish trade agreements with the rebel group will arise. If you choose to be antagonistic, this will be your chance to create a form of economic warfare with the intent of taking over the rebel colony or its resources. You will also have the option to be a good neighbor and provide the rebels with resources they need in return for their services. You can create one big and happy economic family, assuming the rebel colony chooses to go along with your plan. Much will depend on the ability of the rebels to manage their resources, as well as on how sneaky they are; a direct result of the level of difficulty you choose for competition.

This chapter has discussed the background of the dormant comet known as Vulcan's Hammer, as well as other elements of the story exposition that affect the starting conditions of the game. You've also seen that visitors from space can do more damage than a Tyrannosaurus in a hen house, turning an average sunny day on Earth into a nightmare of firestorms, earthquakes, big waves, and widespread destruction. Practical game aspects of the asteroid impact and the futile attempt to divert its course were also mentioned, along with a stirring description of the starship's departure mass in relation to the people on board, a.k.a. "dead weight." Speaking of dead weight, the rise of the rebel leader was outlined, keeping in mind that there are good and bad aspects to having a competitor on the hostile planet you'll be calling "home." All of these topics will be treated in more detail as your eyes roll through the pages that follow.

The next chapter deals with the information any wise traveler would love to have before leaving the Solar System. I'm sure you want to know more about the design of the starship, as well as tips on how to pack clothes for a 50-year journey to an exotic planet. It's tough deciding whether to pack your skis or leave them behind in favor of a solar power satellite, but this book is your handy guide to making those decisions and others that will affect the fate of the human race. Remember those old travel tips: wear layered clothing, don't drink the water, and bring an extra tokamak fusion reactor for emergencies.

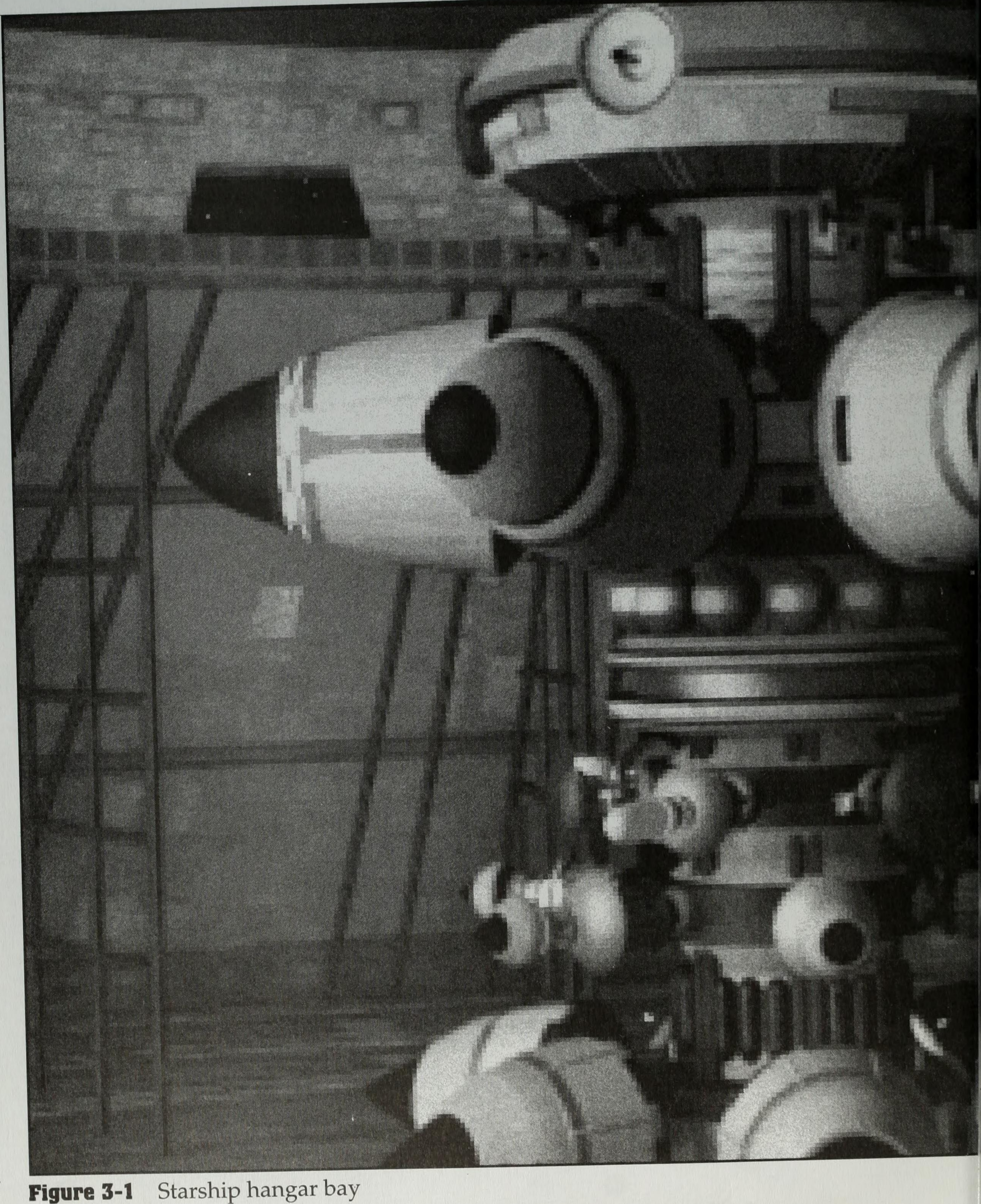
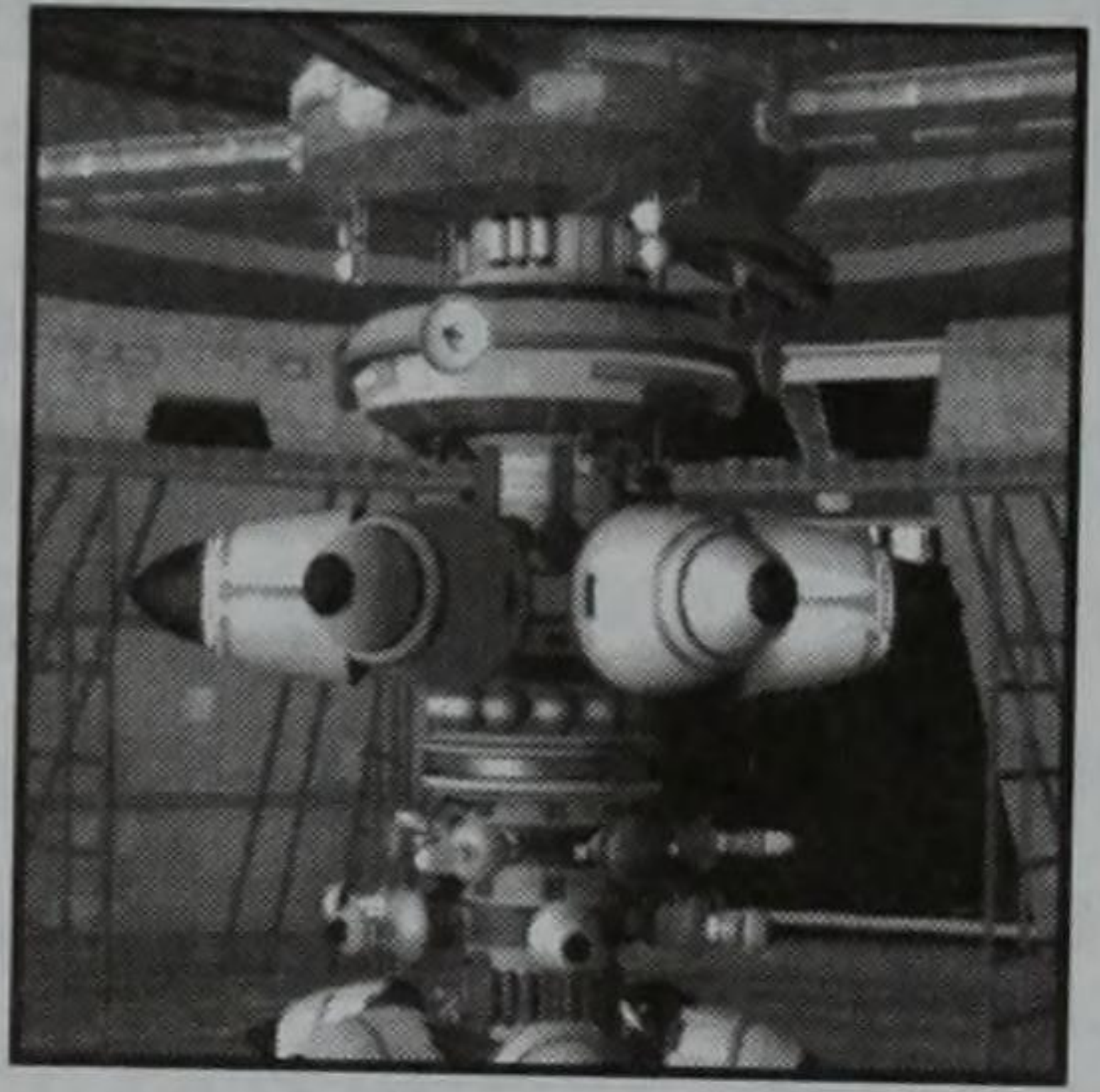


Figure 3-1 Starship hangar bay

3



Preparing for Your Trip

It is difficult to say what is impossible, for the dream of yesterday is the hope of today and the reality of tomorrow.

Robert H. Goddard

There's no getting around it—a journey to another star system is a long trip. The average flight in *Outpost* takes around 50 years. This is one time when any kids in the back seat would be justified in whining, "Are we there yet?"

We're starting with the assumption that, 50 years from now, in the world situation I described in the first chapter, advanced propulsion systems for starships will not have gone through much more testing than they have now. A sudden program to develop such a star drive will have to be based on the most extensive studies that have already been performed, because there won't be enough time to start all of that research from scratch. The basic features of the *Outpost* starship design are considered here, along with an average colonist's view of the accommodations aboard ship.

As a smart traveler, you'll want to plan what to take with you on the trip and what to do with it when you arrive at your destination. You should also be warned about the hazards of space travel. All these topics are covered in this chapter. Don't leave home without it.

Spacecraft Design Considerations and Technical Folderol

Of all the proposed interstellar propulsion systems, nuclear fusion rockets have received the most study. One of the problems with developing a fusion reactor on Earth is that a high vacuum is required to sustain the thermonuclear plasma. In space, the vacuum does not have to be created by artificial means, so it's a natural place for a fusion reactor or a fusion rocket. In a fusion rocket, hot plasma is allowed to "leak" from one end of a magnetic confinement bottle. The exhaust jet from this controlled fusion reactor could also be focused and accelerated through an external magnetic field generated by high-temperature superconducting magnets.

Because fusion rocket research has been so popular, many trajectory optimization studies have been performed for this type of interstellar drive. These studies balance various factors with regard to the design of the starship. Perhaps a longer cruise time is okay if less fusion fuel is used and the mission becomes less expensive as a result. Technological problems might be reduced if the rocket has a lower exhaust velocity, which also makes for a longer trip. The mathematical technique known as the *calculus of variations* is used to perform trajectory optimization, but I won't go into that here because it gives me the willies. These studies have shown that fusion rockets are acceleration limited, not energy limited, for flights to stars in the local neighborhood.

The *Outpost* starship, with its advanced continuous thermonuclear fusion propulsion system, would have an estimated Earth weight of 43 million U.S. tons. By comparison, this is the combined weight of over 500 super aircraft carriers. Because construction of the starship occurs in Earth orbit, the problem of launching all that weight out of the Earth's gravity well is minimized. Figure 3-2 shows the starship under construction in Earth orbit before the fuel rings are added at Jupiter.

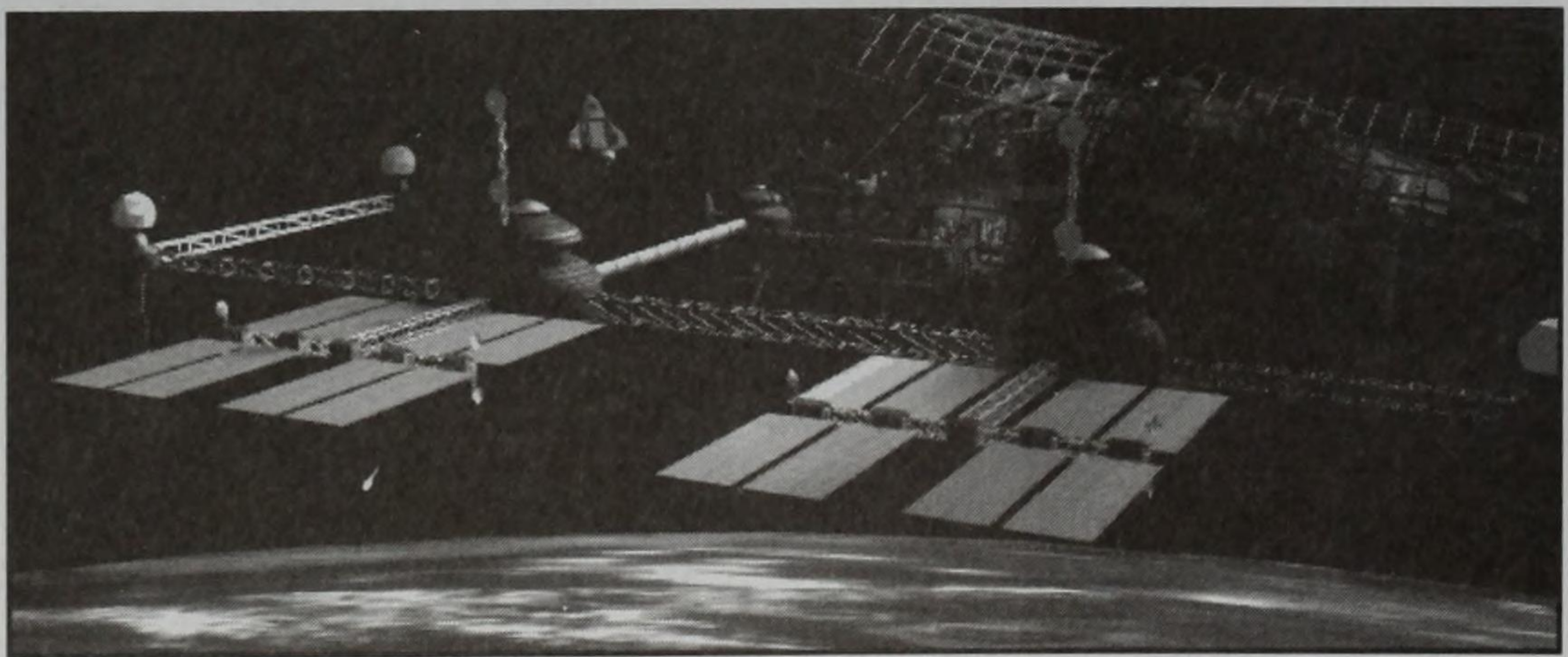
Once the starship is assembled, with its fusion drive, outer frame, and cargo sections, the orbiting drydock is discarded and the entire structure is moved to Jupiter for fueling. At Jupiter, the hydrogen fuel is collected from the atmosphere, then loaded into the fuel rings and stored in solid form at 13 degrees Kelvin. These fuel rings are attached to the frame and dome section of the starship, providing protection against the eroding impact of dust grains and the interstellar medium during the flight. This passive shielding is supplemented with an electrically charged mesh that acts as a protective electrostatic drag screen to divert the kinetic energy of the dust grains. In addition, electromagnetic shields would screen the traveling colonists from cosmic radiation that might otherwise penetrate the ship.

Be the First on Your Block to Own a Nuclear Propulsion System

You want numbers? We've got numbers. Greg Tomko-Pavia, formerly of the *Galileo* navigation team at the Jet Propulsion Laboratory in Pasadena, California, calculated these numbers for our starship design. The *Outpost* starship is capable of accelerating to a cruising speed of 0.2*c*, or two-tenths the speed of light.

Figure 3-2

Starship construction



The alpha particles (in this case, helium nuclei) ejected in the exhaust stream from the fusion drive have an exit velocity of $0.113c$. To accelerate up to $0.2c$ and then decelerate on arrival, the ship has a total mass-to-payload ratio of 36. Given the amount of payload and resources carried by this ship, the cargo/support load is 100,000 tonnes (metric tons). In addition, the engine, structure, and fuel containment vessels raise the payload mass up to 10^6 tonnes. With these considerations, and the ratio given previously, the fully fueled starship has a mass of 36 million tonnes, or 43 million U.S. tons.

When describing space voyages at relativistic speeds, it's important to maintain a rigorous vocabulary for concepts that involve distance and time. Einstein's special theory of relativity demonstrates that measurements of distances or timing of events will vary depending on the relative velocities of the observers performing the measurements. In our case, there are two distinct sets of observers, or "reference frames": those on the starship, and those back on Earth. It is customary to refer to the shipboard frame as the "proper" frame and the Earth frame, in which we also include the destination star system because it's essentially at rest with respect to the Solar System, as the "lab" frame. In some of the discussion that follows, I'll be using the terms *proper* or *lab* depending on the frame of reference.

There are two regimes for describing engine operation. Most often, a rocket will perform accelerations at full throttle, maintaining a uniform fuel consumption rate. This is called *constant proper thrust*. In this regime, the proper acceleration increases steadily as the mass of the rocket drops. As the rocket nears the end of its fuel supply, it often produces very large accelerations if it remains at full throttle. It might therefore be desirable to throttle down the engine in order to maintain *constant proper acceleration*. Our starship operates at full throttle for the entire acceleration phase, although in some cases it might be necessary to reduce thrust gradually during deceleration in order to keep the proper acceleration below $1g$, which is the same gravitational force we feel while living on the Earth.

The fuel consumption rate is between 100 and 300 kilograms per second. At 200 kilograms per second, the fusion drive develops power at 10^{17} watts, releasing the energy of 100 one-megaton bombs each second. This would produce one and a half billion pounds of thrust. At this fuel rate, it takes 4.79 years proper time for the starship to build up to its cruise speed of 0.2*c*. The deceleration phase takes 0.79 year of proper time.

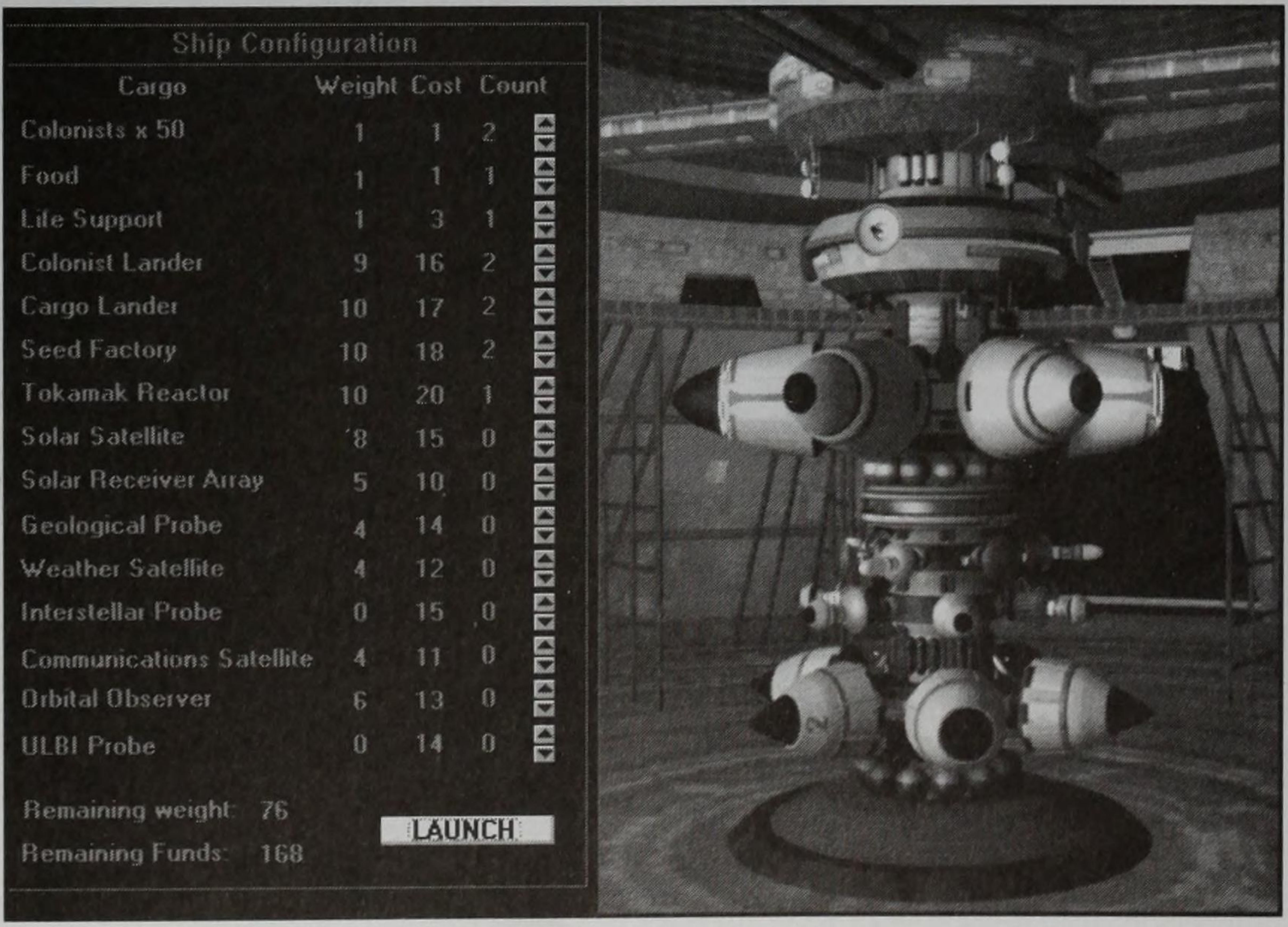
With this design, a trip to a star such as Tau Ceti, which is 11.7 light years away, takes 60.91 years of proper time, which is 62.08 years of Earth time. A trip to Sirius, the Dog Star, which is only 9.5 light years away, takes 50.13 proper years, 51.08 Earth years, or 357.56 dog years. It's a long way to go for a joke, but that's never stopped me before.

Packing Strategies: What to Wear on a Methane Ocean Cruise

Figure 3-3 shows the Ship Configuration screen from the starship building phase of *Outpost*. This is where you have your chance to customize the cargo for your starship, allowing you to initiate your colonization plan. If you've played the game more than once, you will probably have definite opinions about starship packing strategy. On the basis of your experience, you may have decided that an extra weather satellite is more important than a geological probe, or that an extra solar power satellite is more important than both a geological probe and a weather satellite. It's unfortunate, but you can't take everything with you. The starship's propulsion system can push only so much cargo up to a reasonable speed to arrive at the destination within a reasonable amount of time. The early stages of colony development, when much of this equipment and

Figure 3-3

Cargo selection



Ship Configuration

Cargo	Weight	Cost	Count
Colonists x 50	1	1	2
Food	1	1	1
Life Support	1	3	1
Colonist Lander	9	16	2
Cargo Lander	10	17	2
Seed Factory	10	18	2
Tokamak Reactor	10	20	1
Solar Satellite	8	15	0
Solar Receiver Array	5	10	0
Geological Probe	4	14	0
Weather Satellite	4	12	0
Interstellar Probe	0	15	0
Communications Satellite	4	11	0
Orbital Observer	6	13	0
ULBI Probe	0	14	0

Remaining weight: 76

Remaining Funds: 168

material would be used, are crucial to your success. Different planets require different colonization methods, so let's look at some of the equipment packing options and considerations.

Colonists: You must take a minimum of 100 colonists. Each group of 50 colonists has a weight value of 1 and a cost of 1. The colonists you take with you may be the last survivors of the human species, so you might want to take a full load of 200 people. On the other hand, a hostile environment might kill those 200 people if you don't take enough supplies with you in the beginning, so maybe you should take fewer people and more supplies. Tough choice, isn't it? Imagine trying to decide which 200 people would go if this were the real thing. At least you don't have to decide which job skills or personality types you need to make a successful colony. That would be another game in itself. Hmmm.

Food: You must take a minimum of 1 unit of food, which will feed 10 colonists after you've landed on the new planet. Each unit of food has a weight value of 1 and a cost of 1. This is additional food to help keep your colonists alive in case the agricultural dome you build doesn't start producing soon enough. A planetary surface that receives plenty of solar energy will be the optimal place to build an agricultural dome for food production, but you might end up on a planet like Pluto, where the light from the local star would send about as much energy as a 15-watt light bulb down to the planet's surface.

Life Support: You must take a minimum of 1 unit of life support, to be used in case of emergency after you've landed on the new planet. Each unit of life support has a weight value of 1 and a cost of 3. If your explorer robots don't find enough mines right away, or if your mines aren't producing enough life support materials, or if your miner robots disappear beneath the surface of a methane ocean, the amount you buy now might keep people alive a little longer.

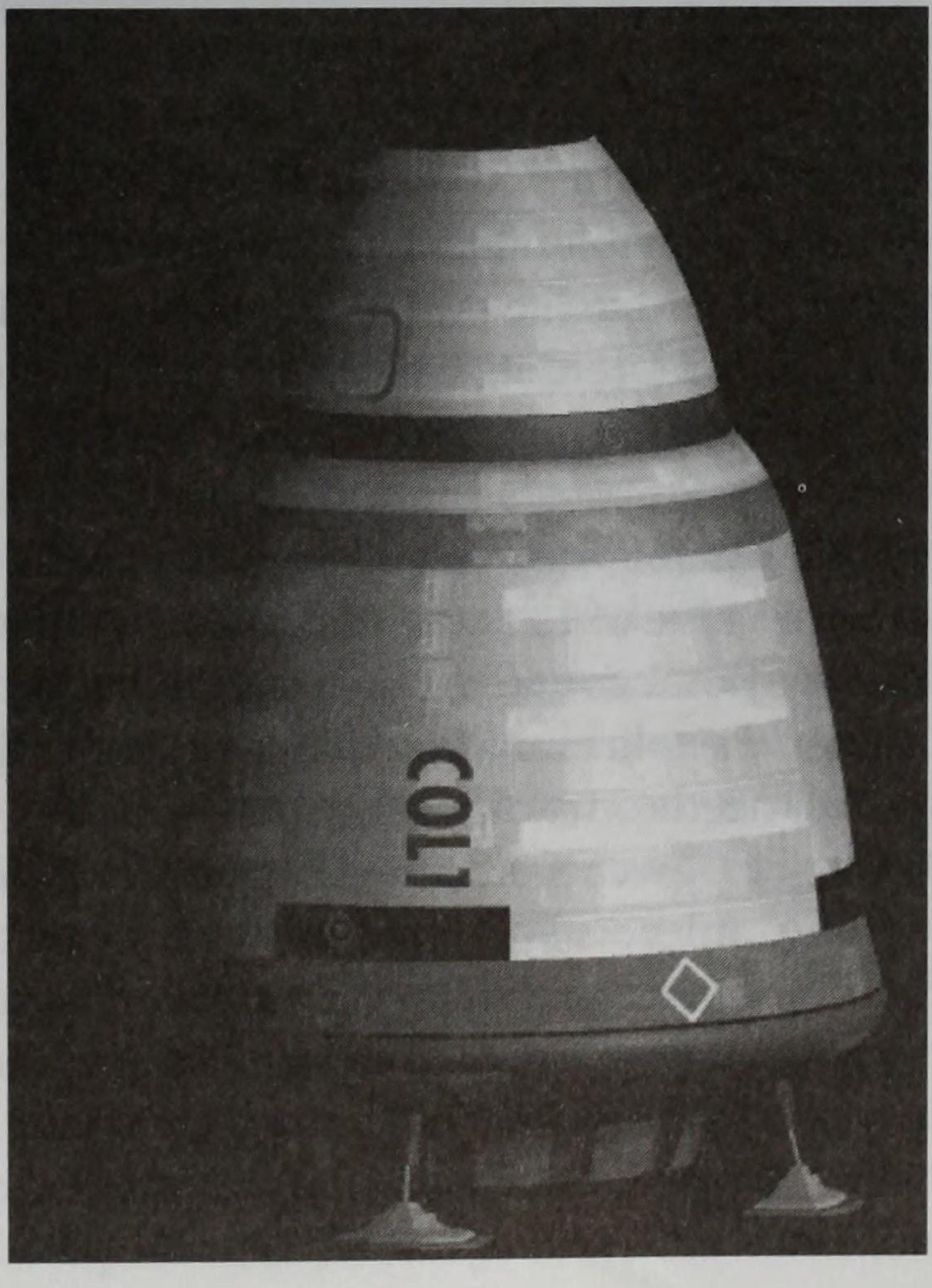
Colonist Lander: You must take a minimum of two colonist landers, because each one can hold only 50 people for a one-way trip to the surface of the new planet. The idea behind this is that it's safer to risk two groups of 50 people in landers than risk the possibility of crashing one lander loaded with 100 people. It's up to you to do the math, so if you arrive at your new planet with 200 people, and you have only three landers, then 50 of them are going to die in orbit, which is really going to have a negative effect on the morale of the colonists who made it to the planet, not to mention the bad feelings your victims are going to have toward you as they die slowly. Each colonist lander, shown in Figure 3-4, has a weight value of 9 and a cost of 16.

Cargo Lander: You must take a minimum of two cargo landers, as shown in Figure 3-5. Each cargo lander, as cargo in the starship, has a weight value of 10 and a cost of 17. Each cargo lander can carry a weight value of 20 down to the surface of the planet. It's a one-way trip for the lander, so it won't be able to return to the starship to pick up another load. Once again, you'll have to compare the weight values of the cargo you need to land on the planet's surface and do the math yourself. Satellites will be placed in orbit directly from the starship, so they don't occupy any of your precious cargo lander space.

Seed Factory: You must take a minimum of two Seed Factories. Each Seed Factory has a weight value of 10 and a cost of 18, but they're well worth it. Not only do they provide basic power, robots, and resource processing facilities, but they'll build a safe habitat so that your colonists can land on the new planet and have a place

Figure 3-4

Colonist lander



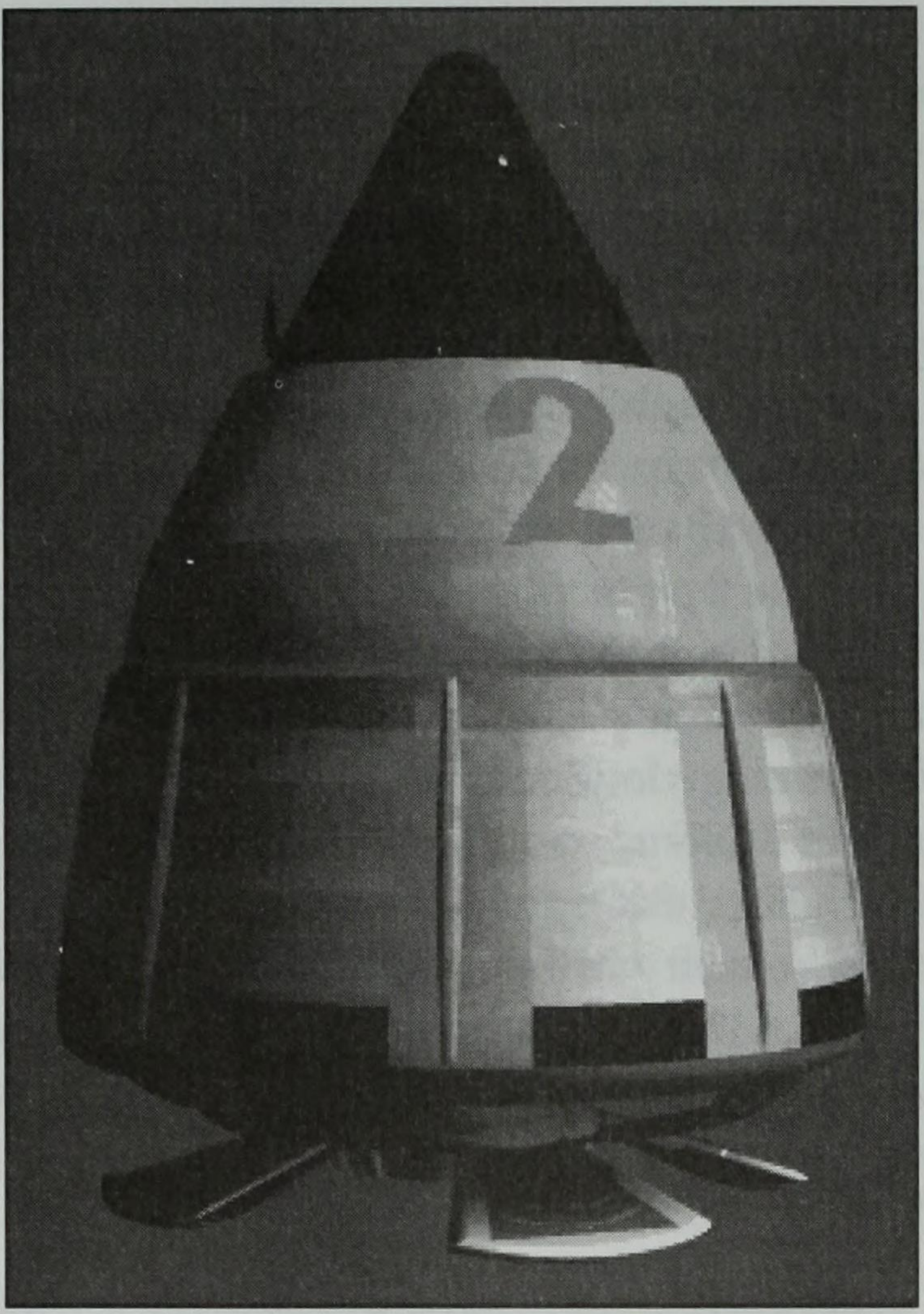


Figure 3-5

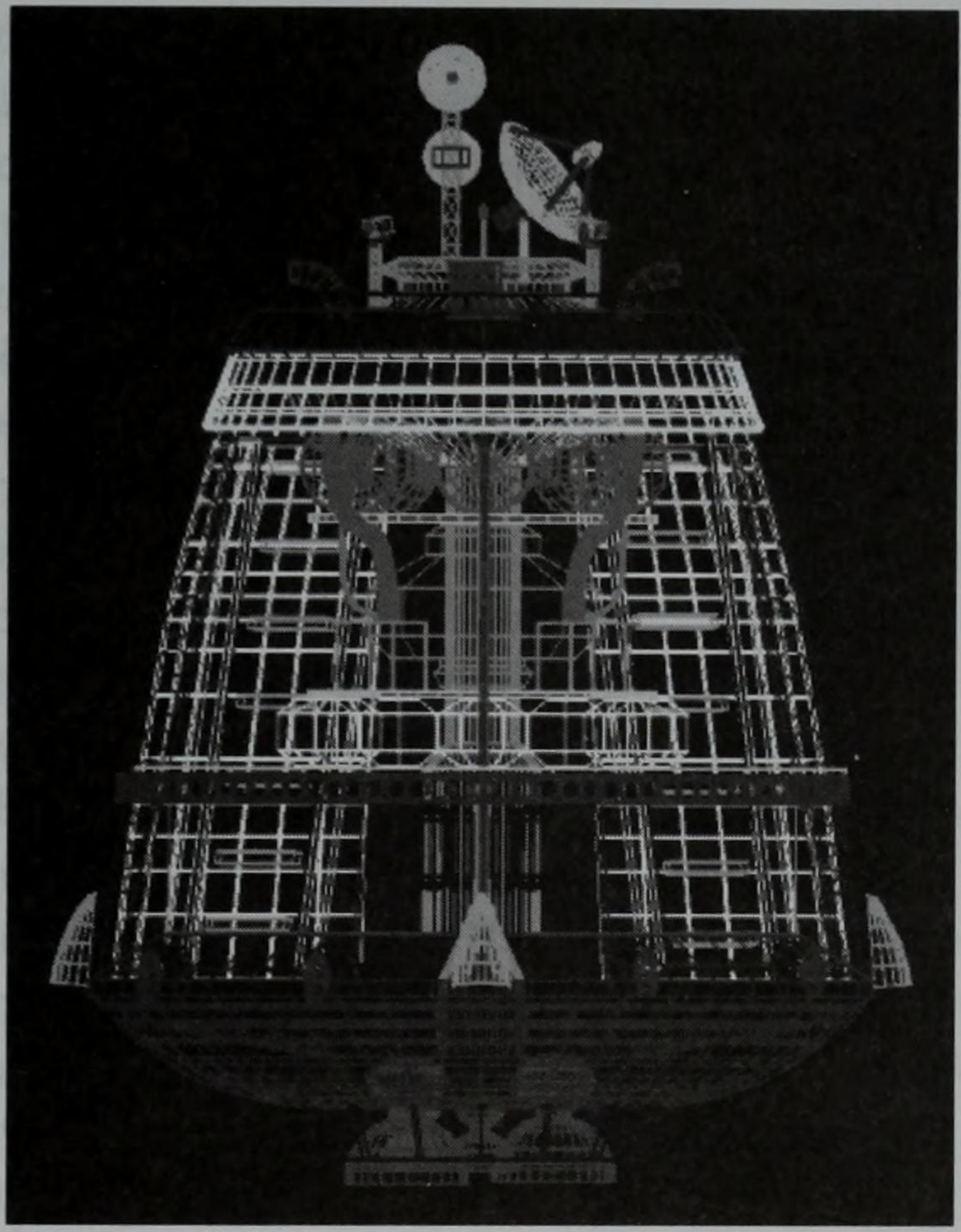
Cargo lander

to live for a while. As is true of the other landers, the Seed Factory cannot return to the starship after it lands. The Seed Factory is discussed in more detail in Chapter 6. A wire-frame model of the empty Seed Factory is shown in Figure 3-6.

Tokamak Reactor: You must take a minimum of one tokamak fusion reactor with you on your trip. Each tokamak reactor has a weight value of 10 and a cost of 20. Because these reactors take so many resources and are so tough to build on the surface of a new planet, the tokamaks you take with you will provide most of your power needs on most planets, except when conditions are optimal for solar power. Because other power sources have an uncertain value until you know more about local conditions on the new planet, the one mandatory reactor in your cargo bay is your power supply life insurance. Be aware that the reactor vessel and its support systems take up half of a cargo lander because it's so large. It won't do you much good if you can't land it on the planet. The tokamak reactor is described in more detail in Chapter 8.

Figure 3-6

Wire-frame Seed Factory



Solar Power Satellite: There is no mandatory number of solar power satellites that you must take with you to the new planet. Each solar power satellite has a weight value of 8 and a cost of 15. On planets that receive enough solar energy from their local stars, the solar power satellite is the cleanest, safest, most reliable, and most powerful source of energy for your colony. On planets that don't receive enough solar energy, the solar power satellite can be almost useless. To make full use of the microwaved power, a solar power satellite must be paired with two solar power receiver arrays on the surface of the planet. Power satellites are wonderful, but you won't be able to build them on your new planet for a long time. The technology is too complicated, and the resources won't be available early in the game for a project of this magnitude. To launch one from your planet, you'll have to develop your space program and heavy lifter technology. So, if you're going to use it, now is the time to get a powersat. Of course, you can't be certain before you leave that you'll be able to use it when you arrive at your destination. You can read more about the solar powersat in Chapter 8 (on power generation) and in Chapter 13 (on satellites).

Solar Power Receiver Array: Solar power receiver arrays, also known as *rectennas*, are not required unless you plan to make use of a solar power satellite, in which case you'll need two receiver arrays to make full use of the microwave power beam. Each receiver array has a weight value of 5 and a cost of 10. These arrays are designed to receive a centimeter-microwave power beam, so they won't do you any good without a solar powersat. You can read more about the solar power system in Chapter 8 (on power generation) and in Chapter 13 (on satellites).

Geological Penetrator Probe: The geological penetrator probe is an optional piece of equipment. Described in detail in Chapter 13, it collects data on local resources before you land on your new planet, helping you decide on the best landing site. Each geological probe has a weight value of 4 and a cost of 14.

Weather Satellite: The weather satellite is an optional piece of equipment. Described in detail in Chapter 13, it keeps an eye on local weather conditions at your new planet. Each weather satellite has a weight value of 4 and a cost of 12.

Interstellar Flyby Probe: The interstellar flyby probe is an optional piece of equipment. Described in detail in Chapter 13, it arrives at your target star system long before you do and sends back detailed data on the planets. Each interstellar probe has a cost of 15 and no weight penalty, as it doesn't occupy space in your cargo bay during the trip.

Communications and Navigation Satellite: The communications and navigation satellite is an optional piece of equipment. Described in detail in Chapter 13, this combined function satellite will be very helpful in robot operations on the planet's surface. Each comsat has a weight value of 4 and a cost of 11.

Orbital Observer: The orbital observer satellite, which people with negative attitudes would call a spy satellite, is an optional piece of equipment. Described in detail in Chapter 13, the observer has an imaging system so that it can maintain a continuous visual study of the planet from orbit, which just happens to include any rebel colonies that might also exist on the same planet. Each orbital observer has a weight value of 6 and a cost of 13.

ULBI Probe: The ultra long baseline interferometer (ULBI) probe is an optional piece of equipment. Described in detail in Chapter 13, the ULBI probes provide high-quality data about your target star system. Each ULBI has a cost of 14 and no weight penalty, as it doesn't occupy space in your cargo bay during the trip.

Travel Insurance: What to Leave in Orbit at Your Destination

Chapter 13 goes into detail on how these pieces of equipment function and serve you. What you should know at this time, however, is that there are tradeoffs to be considered when you select your optional equipment during the ship configuration phase. When you arrive in orbit at your destination, you will be responsible for launching the satellites and probes you brought with you on the voyage. It doesn't matter if you packed the weather satellite inside your starship, it won't launch itself if you drop everyone down to the surface of the planet and forget about satellite deployment. Figure 3-1 shows a full set of landers and satellites ready for launch from the starship's storage bay.

If you pack a geological probe, you can drop it down to the planet's surface to gather the kind of data that will allow you to make the most intelligent decision regarding the landing site of your colony. The artificial intelligence will analyze the data from the surface penetrator and present you with a map of the planet, displaying the best landing areas.

Any solar power satellites you brought with you should be deployed while you're still in orbit. Receiver arrays must be built on the surface of the planet to make use of the solar energy beamed down from the powersat. Until you build those arrays, the powersat will not be providing energy for your colony.

Your weather satellites should also be deployed from orbit. The biggest advantage of keeping track of the weather this way is that you will receive a warning of any major meteorological events about to occur in or around your colony. For example, this is the only way to get an early warning of solar flares, incoming meteors, and powerful dust storms that can do serious damage to your colony and your way of life.

If you have one, you also need to deploy your orbital observer to keep track of what the rebel colony is doing. Trade negotiations, defections among the population, and potential takeovers of rebel colony real estate are all simplified when you can use a spysat to see what your neighbor is doing.

After you've deployed your orbital hardware, you can launch your Seed Factories, cargo landers, and, when the time is right, your colonist landers.

How to Travel to Distant Star Systems on Five Dollars a Day

Although 50 years or more, from the perspective of shipboard time, will have to go by before you arrive at your new star system, the time will pass almost in the blink of an eye. Why is that? Because you'll be asleep for most of the trip. Only emergencies and the occasional exercise period will interrupt your long snooze. While you're asleep, any probes you may have sent ahead of the starship will start sending back data when they arrive at your target star system. This data will help you select the appropriate planet for your colony among the choices in that star system. If no probes have been sent ahead of the starship as a cost-saving measure, you'll just have to take your chances and hope there's something you can live on when you arrive.

If your colonists didn't know each other when they got on the ship, there will be little opportunity to do so during the flight. This may be just as well, because the personalities of a few of them might be enough to drive everyone else nuts. Knowing that everyone would be asleep most of the time, mission planners felt no need to do the type of personality studies so popular in the American astronaut and the Russian cosmonaut programs, which were designed to weed out the people who would end up causing problems during long periods of close confinement. This also explains why one of the colonists, an eminently practical scientist with views directly opposed to yours, manages to talk half of the starship population into starting a separate colony on the surface of the planet. The leader of this rebel group, respected and clever enough that he could get all those people on his side during the exercise periods on the flight, has taken the stand that two colonies will increase the probability of at least one group surviving on the new planet. Therefore, the rebel group will take about half of all your equipment and supplies.

Now, let's take a closer look at those sleeping accommodations aboard the starship.

Sleeping Accommodations

So, you say goodbye to Uncle Obnoxious and the other relatives you're anxious to leave behind, you get on this starship, your luggage is in the cargo bay, and you're so tired that you want to take a nap. You're wondering if you'll be sleeping on a waterbed, a feather bed, a regular mattress, an air mattress, or a futon. Whenever you stop and ask someone about your bed, they laugh as if you've just told a good joke, then keep going. Someone finally takes pity on you and leads you into "the bedroom," with its rows of white, padded sarcophagi. You'll be placed in one of these containers, injected with various fluids, hooked up to intravenous tubes, nearly frozen, attached to life support and monitoring devices, then sealed into your high-pressure oxygen sarcophagus. This will result in a major slowing of your aging process. The travel brochure was quite vague about the sleeping arrangements, so this comes as quite a shock and you're not happy about it. The brochure referred to something called "slow sleep," but you thought it was just a comment on the poor quality of room service. They won't even give you a blanket. You decide to skip the nap and wait as long as possible before you have to go to sleep.

It's not all science fiction. Many animals slow their metabolisms and hibernate so that they can remain asleep without food for days or weeks during the winter. Humans have accidentally been frozen in cold water or buried in snow for several hours, only to be revived from their hypothermia after their hearts were started again and their internal organs were soaked in warm fluids. These people survived without apparent neurological damage because the brain can tolerate the loss of oxygen many times better at low temperatures.

Suspended animation, in which the metabolism is stopped through deep-freezing, with the intent of reviving the person in the future, has not been accomplished except through the freezing of semen and ova. Frozen semen and ova compose the "gene bank" that will travel aboard the starship, preserving more genetic variety than would be available among 200 colonists. There is a chance that medical nanotechnology will be applied to this freezing problem, so that tiny robots could make their way through frozen brain tissue and other organs, repairing the cell damage from extended freezing before the person is reanimated, but this is unlikely to happen in the next 50 years.

Biologists know that cell membranes and organs are not happy when frozen, because the expanding ice destroys cell walls. Cryoprotective agents, such as glycerol and dimethyl sulfoxide, can be infused into tissues before freezing to replace the extracellular water, but the problem with trying to place an entire organism into suspended animation is that different cell types require different freezing and thawing rates.

The "slow sleep" state in *Outpost* is based on the idea that current studies into animal hibernation, bioengineering, and cryobiology will continue. From the accidental freezing of people, doctors have already learned a lot about the reversible effects of hypothermia on humans. This has produced a new rule of emergency medicine: no one who is not both warm and dead should be considered dead. With new medical techniques, it seems as if it's becoming harder and harder to define "death." Of course, the colonists on the *Outpost* starship will require a great deal of trust in the technology, because it could not have been tested for a 50-year period before they try it themselves. This would tend to put off a lot of potential candidates for colonization, who would rather take their chances with an incoming asteroid than submit themselves to suspended animation, which would sound suspiciously like death to most people.

The Hazards of Foreign Travel

Sure, travel to exotic destinations is exciting, but there are certain environmental hazards involved that your travel agent might not tell you about.

If you're one of those party animals that likes to get drunk, naked, and go for a walk outside, there are going to be problems. Let's say you're still on the starship, but you're up for one of those brief exercise periods that occur every few years. You're groggy and weak from sleeping so long, so you open an airlock and step outside for a breath of fresh air. Whoops! Imagine the amusement of your friends as they watch you float past the windows, always the life of the party, acting surprised at your situation.

Your death would be quick, but not unpleasant. The lack of oxygen would make you giddy and might even cause you to die laughing, if you could laugh in a vacuum. Although it makes for a dramatic scene in a science fiction movie, you would not explode because your skin is too tough and resilient for that. You'd pass out after about 10 to 15 seconds, so you'd only have time to feel the shock of the cold, which would turn your perspiration to ice and make your skin tingle, and the experience of the air rushing out of your lungs. If you kept your eyes open, and I know I would, your vision would blur.

The oxygen would leave your blood and brain in a few minutes; this hypoxia would be your cause of death. Afterwards, your skin would blister as the water in your body evaporated over the next few days. Some bruises would appear on your skin from broken blood vessels, as they did with the three cosmonauts on *Soyuz-11* in 1971, who were returning home when a valve popped open and released the air from their cabin. Unfortunately, this is how we know so much about the effects of death in space. The cosmonauts died in their seats with peaceful expressions on their faces.

Floating in space, your body would become mummified and preserved from decay. The skeletal structure would keep it from shrinking much, although it would weigh less due to the evaporation of the water from your system. Over a long period of time, the skin would not change much in color, even if it were exposed to light, although it would deteriorate. Nothing would detach from the body unless it hit something else. After dying in orbit around Earth this way, you could remain a small satellite for many years until you made your final descent into the atmosphere and became a streak of light in the sky, disappearing in a blaze as if you were a meteorite.

Well, at least you'll be safer on the surface of a planet, right? That depends on the planet. Earth has that handy magnetic field and atmosphere hanging around to keep most of the bad things from reaching the surface of the planet. Meteorites usually burn up before they hit the ground, ultraviolet radiation is absorbed by the atmosphere, and the radiation from solar flares is dissipated without harm to the humans who live here. Most other planets don't have that basic atmospheric line of defense.

A solar flare generating 1,000 to 7,000 rads, uninhibited by any appreciable atmosphere, would kill anyone exposed to it on a planetary surface. In fact, an exposure of only 50 rads or less would not manifest obvious effects on a human. The safest place to be in the event of a solar flare, on a planet without a decent atmosphere, would be under 30 feet of dirt. This is one of the reasons why as many structures as possible are built underground in *Outpost*. Surface structures, which are heavily shielded against the normal bombardment of cosmic radiation, must be evacuated in the event of a solar flare. The surface is not a nice place to be, in most cases. When you consider that radiation exposure is cumulative, even consistent small doses of radiation over a long period of time would have bad results on a human body.

Okay, so you've been exposed to 1,000 rads. How long have you got? Four to six days of vomiting and diarrhea. Higher doses might kill you in a few hours from nervous system collapse, during which you could look forward to convulsions, blindness, and seizures.

As the travel agent will tell you, bad things will not happen to you every time you venture out into space, but accidents happen. Hostile planets have dust storms, meteorite strikes, and numerous other hazards that can nail you when you aren't looking, but there are often precautions you can take to alert you to impending danger. Just be a smart traveler, keep your eyes open, don't open any airlock doors without asking first, and have a nice trip.

Because this is the highest form of adventure travel, the new space traveler must take the time and effort to prepare for this journey with great care. The packing decisions you make as the starship is being built will have a direct impact on your future and the success of your colony. Your options have been defined in this chapter. The satellites you choose to leave in orbit when you arrive at your destination will determine the quality of information you have about your new environment. It would be nice to take everybody and every kind of equipment with you, but practical limitations define the size of the starship and the cargo mass that can be driven by the nuclear propulsion system.

The next chapter will help you choose a destination for your colonization effort. Your probes will provide you with basic data about your choices, but you'll be better off in the long run if you know enough about planetary science to make an educated guess. There is no second chance for the people on your starship…unless, of course, you start the game over again.

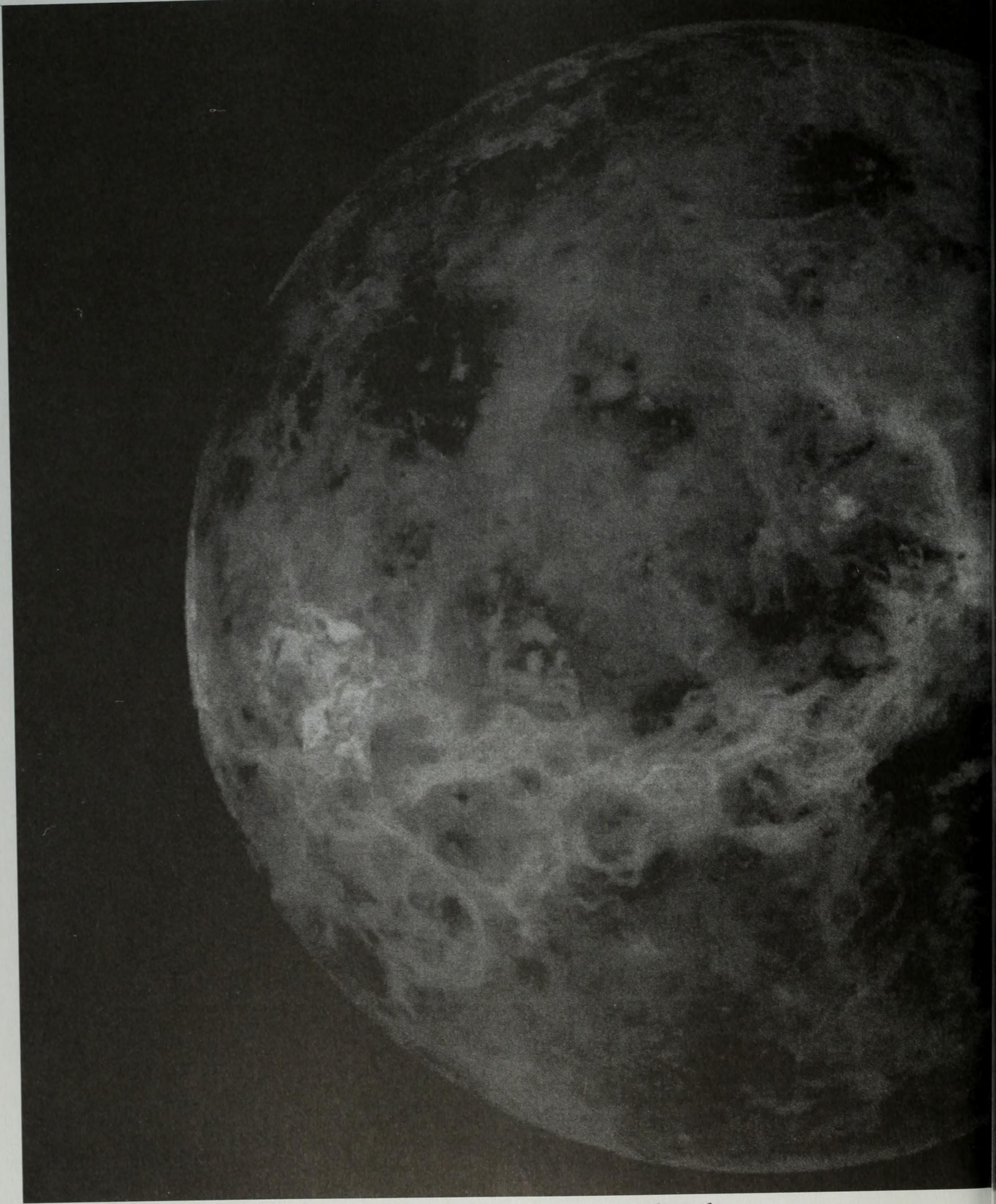
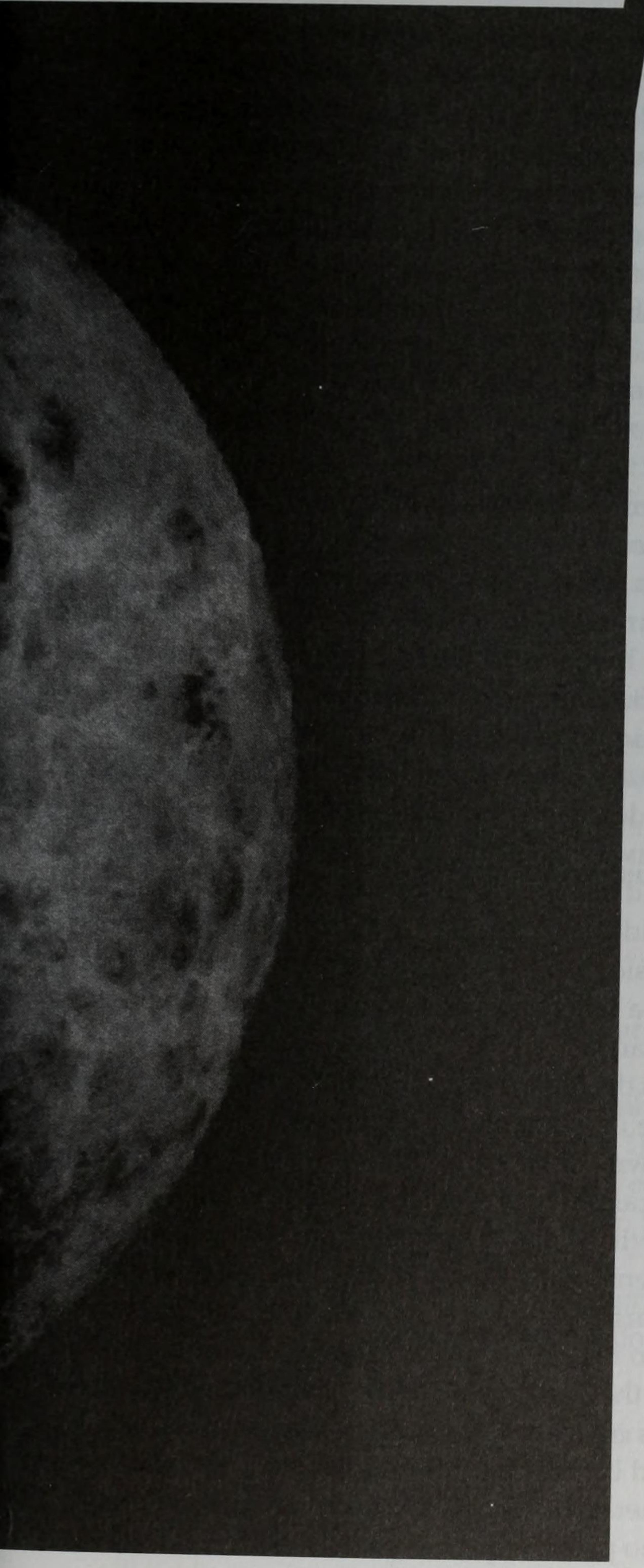


Figure 4-1 Venus: A tough place to visit…and you have to live there.



4

Choosing a Destination

Is it not astonishing that nearly all the inhabitants of our Planet, down to our times, have lived and died without knowing where they are, and without having the slightest conception of the marvels of our universe?

Camille Flammarion,
French Astronomer (1842-1925)

Are you all dressed up with no place to go? Do your feet have that itchy feeling that lets you know they crave exotic soil to walk on? Do you want to avoid almost certain death by leaving the Earth before Vulcan's Hammer whacks you on the head? If you answered yes to any of these questions, you need to read this chapter to find out why you can't just move to another planet in the Solar System, where you might go on your interstellar voyage, and what happens to chickens who spend too much time in high-gravity environments.

Your Travel Agent Can't Help You Now

I'm sure you've been wondering why you can't just pack your toothbrush and move to Mars. Well, I'll tell you why not. It's not safe there. In fact, there isn't any safe place to hide in the Solar System. You could move the survivors of human civilization to the Moon and have a great seat to watch the fireworks as the asteroid strikes the Earth, but they'd really be annoyed with you when the same thing happens to them. Multiple comets will be passing through the Solar System because of a *brown dwarf*. I'm not referring to a midget with a nice tan, but to a family of "superplanets" that have histories similar to Jupiter and Saturn, which might be considered small members of that family. If Jupiter were far enough away from the Sun that it couldn't shine by reflected light, it would be called a *black dwarf*. If Jupiter were about 80 times larger, it could get hot enough at its core to begin thermonuclear hydrogen fusion and become a star. So, a brown dwarf might be considered a failed star, and you know how obnoxious and vindictive they can be.

Vulcan's Hammer is the first of several comets pulled out of their orbits by the passage of the brown dwarf outside the Solar System. In fact, the brown dwarf escorts a huge swarm of its own comets through the galaxy, losing large numbers of them as they interact with the gravitational attraction of the star systems they pass. Those star systems also give up some of their comets to the attractive brown dwarf passing by. As most of the visiting comets penetrate deeper into the Solar System, they would develop the characteristic tails as they become heated by the solar wind. While some of these comets could develop stable orbits around the Sun, many of them would be attracted to the planets they encounter, pulverizing the planetary surfaces with vast amounts of energy. As a result, there is no place for your colonists to hide in the Solar System when the time comes to leave the Earth.

Turn Left When You Reach Alpha Centauri

The intelligent traveler makes decisions based on the best data available about the destination. You have an array of data-gathering methods, described elsewhere in this book, designed to give you the most complete information possible. In Chapter 21, you'll find a listing of the *Outpost* star systems and the probability of each system having terrestrial planets for you to colonize. The game allows you to send various probes ahead of your starship to collect data about possible destinations. When you have selected your destination, the artificial intelligence piloting the starship will work out an optimized trajectory so that you can sleep securely during the long voyage. The planets themselves fall into the same categories as those in our Solar System, which means they have good points and bad points. These considerations must be balanced before you make your final orbital insertion and aerobraking maneuvers. You will have enough fuel to make only one planetfall, so your first choice needs to be the right one.

Looking for Terrestrial Planets in All the Wrong Places

Outpost uses the planets in our own Solar System as representative of planetary types. Here are their physical characteristics with some comparisons to Earth.

MERCURY

Equatorial diameter (Earth = 1)	0.38
In kilometers	4,878
Mass (Earth = 1)	0.055
Rotation period	58.6 days
Surface gravity (Earth = 1)	0.38
Mean distance (in astronomical units, or AU) from Sun (Earth = 1)	0.387
Solar energy received (Earth = 1)	6.6
Approximate mean temperature (Centigrade)	350(day), -170 (night)
Principal atmospheric gases	Helium trace
Escape velocity (kilometers per second)	4.25

VENUS

Equatorial diameter (Earth = 1)	0.95
In kilometers	12,104
Mass (Earth = 1)	0.815
Rotation period	243 days, retrograde
Surface gravity (Earth = 1)	0.91

Mean distance (in AU) from Sun (Earth = 1)	0.723
Solar energy received (Earth = 1)	2.2
Approximate mean temperature (Centigrade)	450(surface) -23 (clouds)
Principal atmospheric gases	Carbon dioxide, nitrogen
Escape velocity (kilometers per second)	10.36

EARTH

Equatorial diameter (Earth = 1)	1.0
In kilometers	12,756
Mass (Earth = 1)	1.0
Rotation period	23.94 hours
Surface gravity (Earth = 1)	1.0
Mean distance (in AU) from Sun (Earth = 1)	1.0
Solar energy received (Earth = 1)	1.0
Approximate mean temperature (Centigrade)	22 (average)
Principal atmospheric gases	Nitrogen, oxygen
Escape velocity (kilometers per second)	11.18

MARS

Equatorial diameter (Earth = 1)	0.53
In kilometers	6,794
Mass (Earth = 1)	0.11
Rotation period	24.62 hours
Surface gravity (Earth = 1)	0.38
Mean distance (in AU) from Sun (Earth = 1)	1.52
Solar energy received (Earth = 1)	0.44
Approximate mean temperature (Centigrade)	-23 (average)
Principal atmospheric gases	Carbon dioxide, nitrogen
Escape velocity (kilometers per second)	5.02

JUPITER

Equatorial diameter (Earth = 1)	11.19
In kilometers	142,800

Mass (Earth = 1)	318.0
Rotation period	9.84 hours
Surface gravity (Earth = 1)	2.69
Mean distance (in AU) from Sun (Earth = 1)	5.2
Solar energy received (Earth = 1)	0.037
Approximate mean temperature (Centigrade)	-150
Principal atmospheric gases	Hydrogen, helium
Escape velocity (kilometers per second)	59.6

SATURN

Equatorial diameter (Earth = 1)	9.41
In kilometers	120,000
Mass (Earth = 1)	94
Rotation period	10.23 hours
Surface gravity (Earth = 1)	1.19
Mean distance (in AU) from Sun (Earth = 1)	9.54
Solar energy received (Earth = 1)	0.011
Approximate mean temperature (Centigrade)	-180
Principal atmospheric gases	Hydrogen, helium
Escape velocity (kilometers per second)	35.6

URANUS

Equatorial diameter (Earth = 1)	4.11
In kilometers	52,400
Mass (Earth = 1)	14.6
Rotation period	17.9 hours, retrograde
Surface gravity (Earth = 1)	0.91
Mean distance (in AU) from Sun (Earth = 1)	19.19
Solar energy received (Earth = 1)	0.003
Approximate mean temperature (Centigrade)	-210
Principal atmospheric gases	Hydrogen, helium
Escape velocity (kilometers per second)	21.3

NEPTUNE

Equatorial diameter (Earth = 1)	3.95
In kilometers	50,400

Mass (Earth = 1)	17.2
Rotation period	16 hours
Surface gravity (Earth = 1)	1.19
Mean distance (in AU) from Sun (Earth = 1)	30.06
Solar energy received (Earth = 1)	0.001
Approximate mean temperature (Centigrade)	-220
Principal atmospheric gases	Hydrogen, helium
Escape velocity (kilometers per second)	23.3

PLUTO

Equatorial diameter (Earth = 1)	0.18
In kilometers	2,300
Mass (Earth = 1)	0.002
Rotation period	6.4 days, retrograde
Surface gravity (Earth = 1)	0.04
Mean distance (in AU) from Sun (Earth = 1)	39.52
Solar energy received (Earth = 1)	0.0006
Approximate mean temperature (Centigrade)	-230
Principal atmospheric gases	Traces of methane and carbon dioxide
Escape velocity (kilometers per second)	1.1

CERES ASTEROID

Equatorial diameter (Earth = 1)	0.074
In kilometers	940
Mass (Earth = 1)	0.00017
Rotation period	9.08 hours
Surface gravity (Earth = 1)	0.01
Mean distance (in AU) from Sun (Earth = 1)	2.8
Solar energy received (Earth = 1)	0.43
Approximate mean temperature (Centigrade)	-38
Principal atmospheric gases	None
Escape velocity (kilometers per second)	Negligible

PHOBOS

Equatorial diameter (Earth = 1)	0.002
In kilometers	22

Mass (Earth = 1)	0.000000018
Rotation period	0.32 days
Surface gravity (Earth = 1)	0.001
Mean distance (in AU) from Sun (Earth = 1)	1.52
Solar energy received (Earth = 1)	0.43
Approximate mean temperature (Centigrade)	-50
Principal atmospheric gases	None
Escape velocity (kilometers per second)	Negligible

Can You Drink the Water When You Get There?

When you arrive at your destination, you're going to have to adapt your routine to the local environment. Because the atmosphere won't be friendly, outdoor activities such as sunbathing, and breathing, for that matter, will be out of the question. Heavy shielding will be required for surface buildings, and what little is required in terms of outdoor human operations will have to be brief, in beefed-up spacesuits. Robots will perform outdoor labor.

Most of your time will be spent underground, where your body will be protected from cosmic radiation by over 100 feet of dirt. The local gravity will also require some getting used to, as weaker gravities will be common and stronger gravities will be possible. If the gravity is very weak, you might run into an outdoor situation where you jump up to grab something and find that your legs have propelled you into orbit. On a stronger-gravity planet, you might find that it's exhausting to move around for a while, but that your muscles will adapt by getting larger and stronger.

Experiments performed at the University of California, Davis, in the 1970s demonstrated the effects of long-term exposure to a high-gravity environment. Flocks of chickens were placed into two centrifuges in CARL, the Chronic Acceleration Research Laboratory. These chickens spent 3 to 6 months under a constant pull of 2.5 *g*, instead of the normal Earth gravity of 1 *g*. They laid their eggs, cackled, organized hen parties, clucked fowl-mouthed insults at the eggheads outside the centrifuge, and came to believe that life in a high-*g* environment was normal. When it was time to leave the centrifuge, a normal-sized chicken that had entered the accelerator months earlier would come out looking like the Arnold Schwarzenegger of chickens, able to beat the stuffing out of a regular chicken, or any other barnyard animal. Dubbed *Great Mambo Chicken*, these fowl had not only lost their excess body fat, but their hearts were stronger and their muscles were huge. We can infer from this study that humans living in a high-*g* environment will turn into chickens…or they'll get stronger.

How to Avoid Paying Taxes by Leaving the Earth

Leaving the planet is the greatest tax dodge of all time. Try it yourself. Move to another star system and see if the Internal Revenue Service bothers to follow you. The agency you have to watch out for is U.S. Customs.

Skip Nunamaker, a NASA administrator at the Ames Research Center in California, received an unusual assignment regarding the *Pioneer Venus 2* mission. Four titanium probes, which were designed to study the Venusian atmosphere and weather, were to be dropped to the hellish surface of Venus in 1978. Because the probe instruments required observational or sampling access to the hostile atmosphere, 14 sapphire windows were sealed into the pressure vessels. A tougher diamond window was deemed necessary to provide an optically clear shield on one of the probes. The problem was that the window would be larger than any available diamond. A diamond broker in Amsterdam was hired to watch for the largest diamonds passing through town.

After a long search, two diamonds turned up that fit the NASA requirements. They were purchased, then a diamond cutter shaped the two diamonds to NASA specifications. When they were ready, they were placed in a velvet-lined briefcase and attached to the arm of Skip Nunamaker, who was quite nervous about transporting such a valuable cargo on his commercial flight. Returning to California, he had to pass through U.S. Customs at the airport. When asked if he had anything to declare, Nunamaker showed them the diamonds in the briefcase and explained the situation. Customs required NASA to pay a large amount of duty on the diamonds before they'd allow them into the country. A lot of phone calls were made while Nunamaker spent the day at the airport, then a deal was made and NASA came through with a check.

In August of 1978, *Pioneer Venus 2* was launched, proudly wearing its diamond window. Hearing of the launch, U.S. Customs refunded the duty amount to NASA, as the diamonds had left the country.

Now that you know more about your interstellar travel options, let's get into the details of using *Outpost*. The next chapter will walk you through the interface screens, getting your colony started, the map, the reporting system, using the artificially intelligent advisor, how to turn the options on and off, and how to make use of the full capability of the simulation.

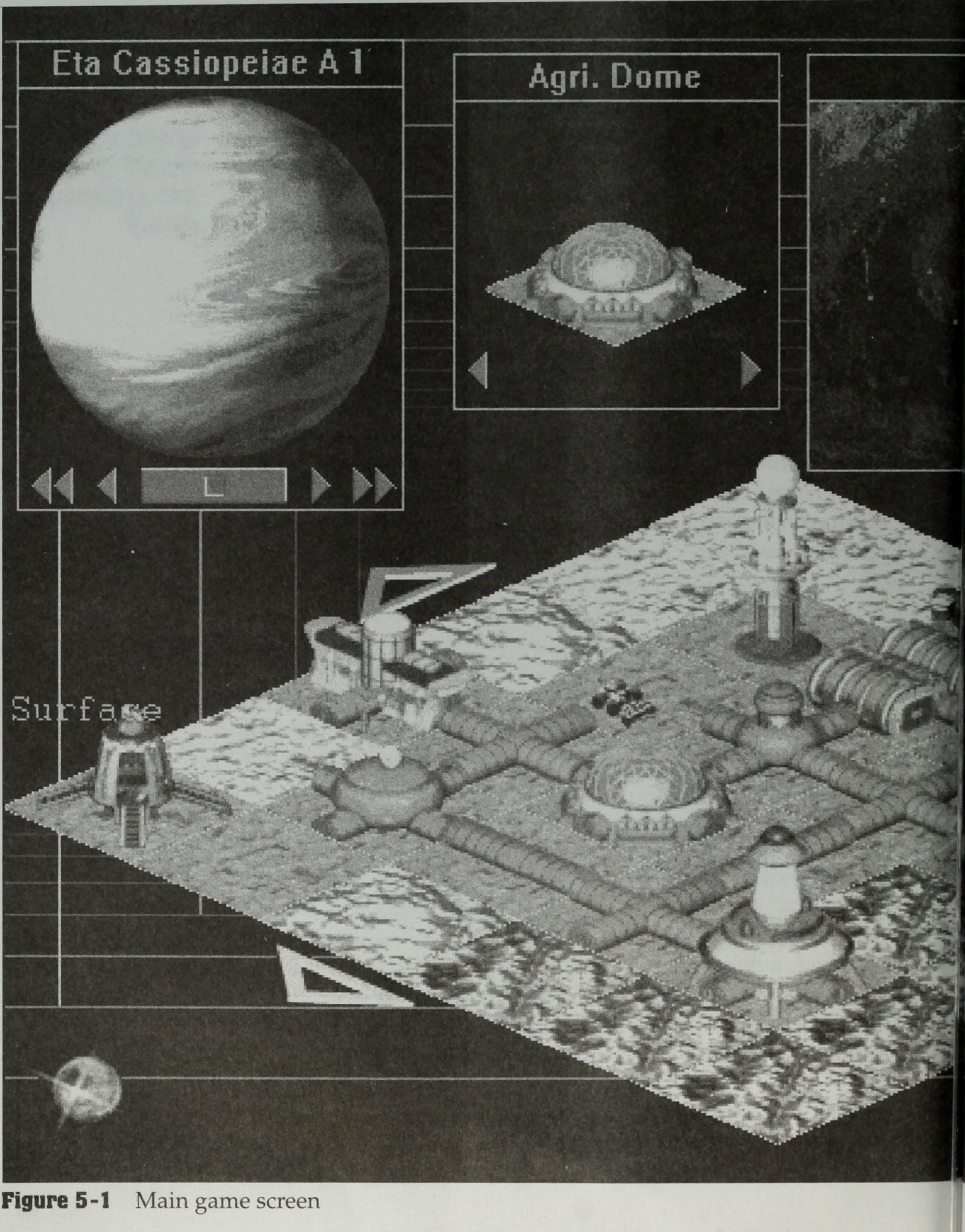

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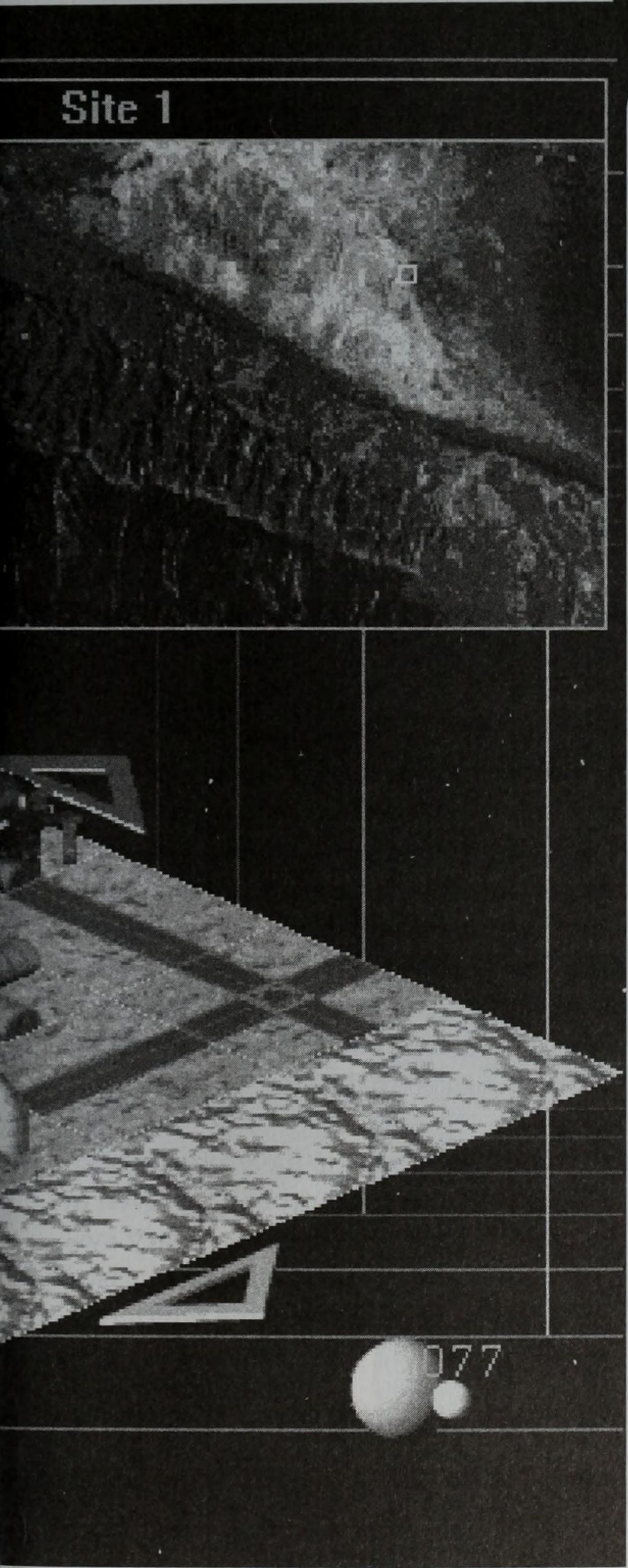
Figure 5-1 Main game screen



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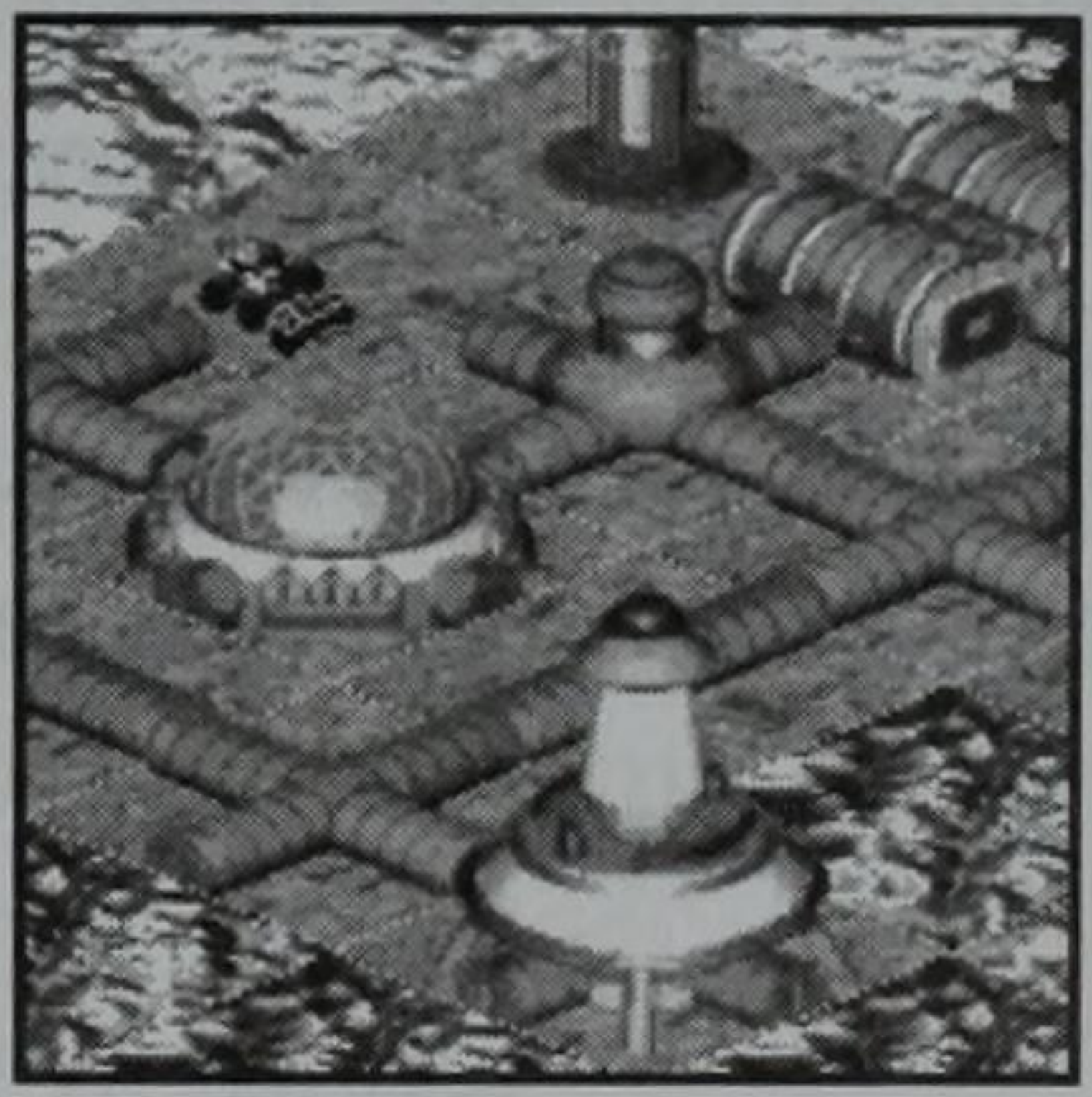


Tutorial/Reference

Let us treat men and women well; treat them as if they were real; perhaps they are.

R. W. Emerson, American essayist

You have full control over the details of *Outpost* operations. Armed only with the advice of your artificial intelligence (AI) personality, whose name you will choose during the opening phase of the game, you must make crucial decisions that will affect hundreds of digital lives. To make those decisions, you must know how to operate the various controls that are part of the game interface. The manual included with the game is still the best source of information regarding installation procedures and the specific interface for your computer, but this chapter is meant to add informative details beyond what's covered in the manual.

This chapter discusses the naming of your AI and colony elements, the probe targeting process, the packing and launch of your starship, how to get one or more colonies started on your new planet, how to set the difficulty level, how the game handles time, where to find help, getting advice from the AI, the operation of the reporting system, terrain types, and how to shut off some of the features for faster gameplay on slower computers.

The Front End

Your first big decision in *Outpost* involves the naming of your artificial intelligence. The AI will introduce itself after the opening animation sequence, at which time you will be asked what name you'd like to give the AI. Although this may not seem like a crucial decision, I'm sure you can imagine what kind of personality damage a name such as "Stupid" can do to a child or a young AI. With a name such as Stupid, people are generally going to assume that your AI is of substandard intelligence. You can name the AI anything you wish within the character limit, but you'll also have to live with it throughout the game, so make sure you like your choice.

Details on packing considerations for your trip have already been covered in Chapter 3. Details on satellites and probes are given in Chapter 13. Details on individual stars and their planetary systems are given in Chapter 21. These three topics will be discussed in this chapter only as they directly relate to the game interface.

Probe Targeting

Your first major decision involves the targeting of up to four probes to different star systems that you'd like to investigate, which you select by clicking on the star name or the box beside it. You begin the game with the knowledge of what has been discovered from Earth, allowing you to make some assumptions about star systems that might contain planets. From the Targeting screen, this information is available to you by clicking on the stars. This includes the distance of the star system from Earth, as well as the projected travel time to that star based on the type of starship engine you'll be using. An example of the Probe Targeting display, where this decision is made, is shown in Figure 5-2.

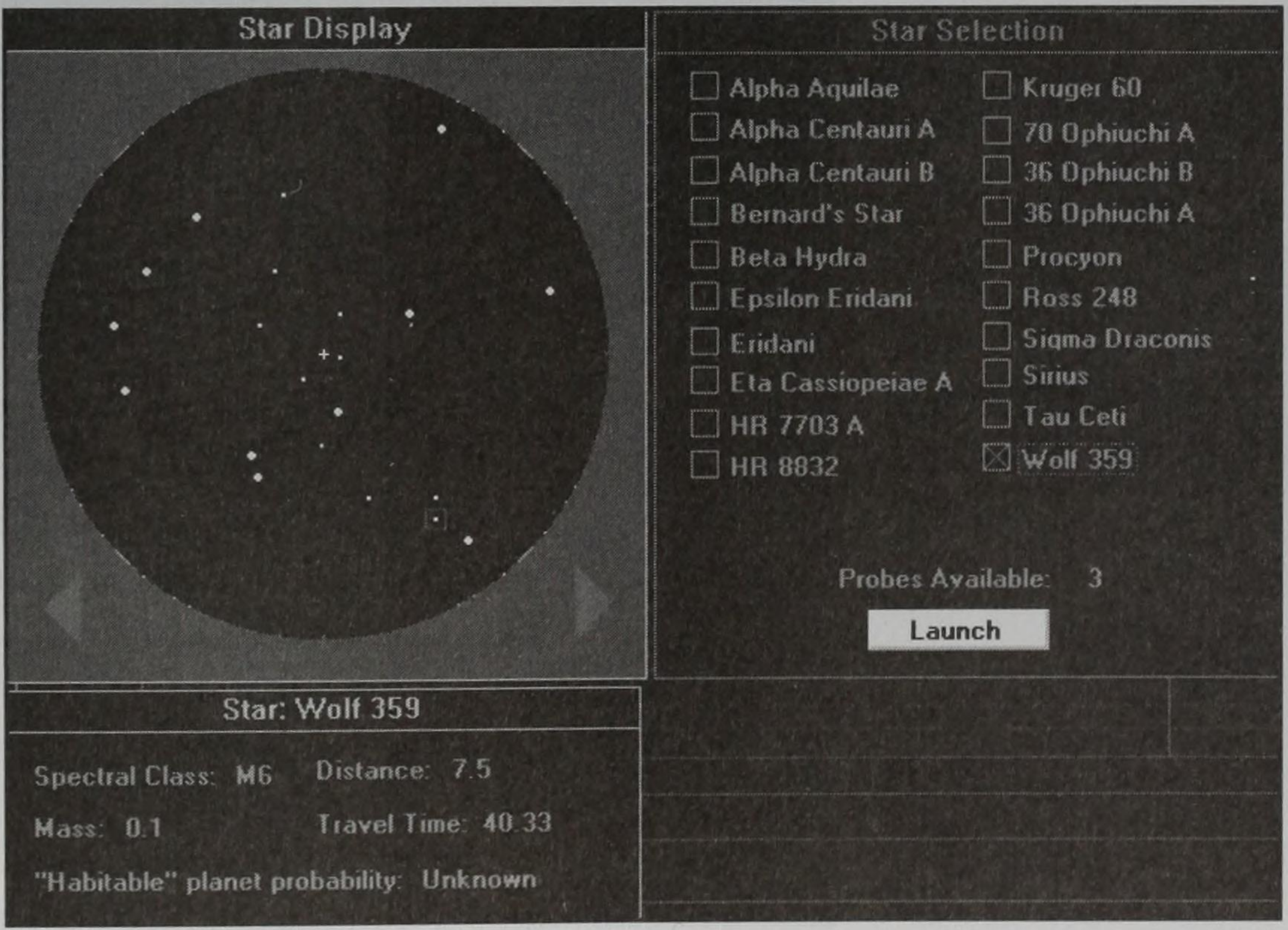
Chapter 22 describes the process of detecting planetary systems and the requirements for star systems that could contain habitable terrestrial planets. If there's a Jovian, or gas giant, type of planet in a star system, there's also a good chance of finding a terrestrial planet in that system, but there are no guarantees. You can't live on a Jovian planet, so it will be quite an annoyance to your colonists if you arrive in a star system without any terrestrial planets.

Packing

The Ship Configuration screen, as shown in Chapter 3, allows you to choose the exact items you want to load into your cargo bays for the long trip on the starship. This is the only point in the game where you have an actual monetary budget, as well as a weight limit. While you're still on Earth, monetary considerations still apply, but the main limiting factor is the amount of mass you can transport as cargo with a single starship. At this point, you also have to decide whether to bring extra colonists, and save a few

Figure 5-2

Probe Targeting display



☐ Alpha Aquilae
☐ Alpha Centauri A
☐ Alpha Centauri B
☐ Bernard's Star
☐ Beta Hydra
☐ Epsilon Eridani
☐ Eridani
☐ Eta Cassiopeiae A
☐ HR 7703 A
☐ HR 8832
☐ Kruger 60
☐ 70 Ophiuchi A
☐ 36 Ophiuchi B
☐ 36 Ophiuchi A
☐ Procyon
☐ Ross 248
☐ Sigma Draconis
☐ Sirius
☐ Tau Ceti
☒ Wolf 359

Probes Available: 3

Star: Wolf 359

Spectral Class: M6
Distance: 7.5
Mass: 0.1
Travel Time: 40.33
"Habitable" planet probability: Unknown

extra people from destruction, or to stay with the minimum number of people and provide them with the kind of support equipment that will enhance their chances for survival. Both strategies are valid, but you must decide what's most important.

Launch

During the starship fueling process at Jupiter, you have two launch opportunities. The data returning from the VLBI (very long baseline interferometer) probes will help you decide which star systems have the highest probabilities of habitable planets. If you purchased ULBI (ultralong baseline interferometer) probes from the Ship Configuration screen, you can now launch these probes to collect data, such as the number and type of planets, on the one star system you've chosen to colonize. The AI will let you know when the probes are ready to begin their journey.

The second launch involves the colonization starship itself. When the fueling process has been completed, the AI will notify you that the ship is ready for launch. If you allow the AI to select a destination, you'll just have to trust it to make a good decision because there won't be any second chances. If you make the decision, you'll have to trust yourself to make a good decision. Which is better? That's up to you.

During your journey, another launch opportunity will arise if you purchased an interstellar flyby probe. The flyby uses the same type of propulsion system as the starship, but its payload and mass are insignificant in comparison to the starship, so it can move much faster. The information gathered from this probe will help you choose which planet to colonize when you arrive. Your flight trajectory will also be adjusted with updated location information from the flyby probe.

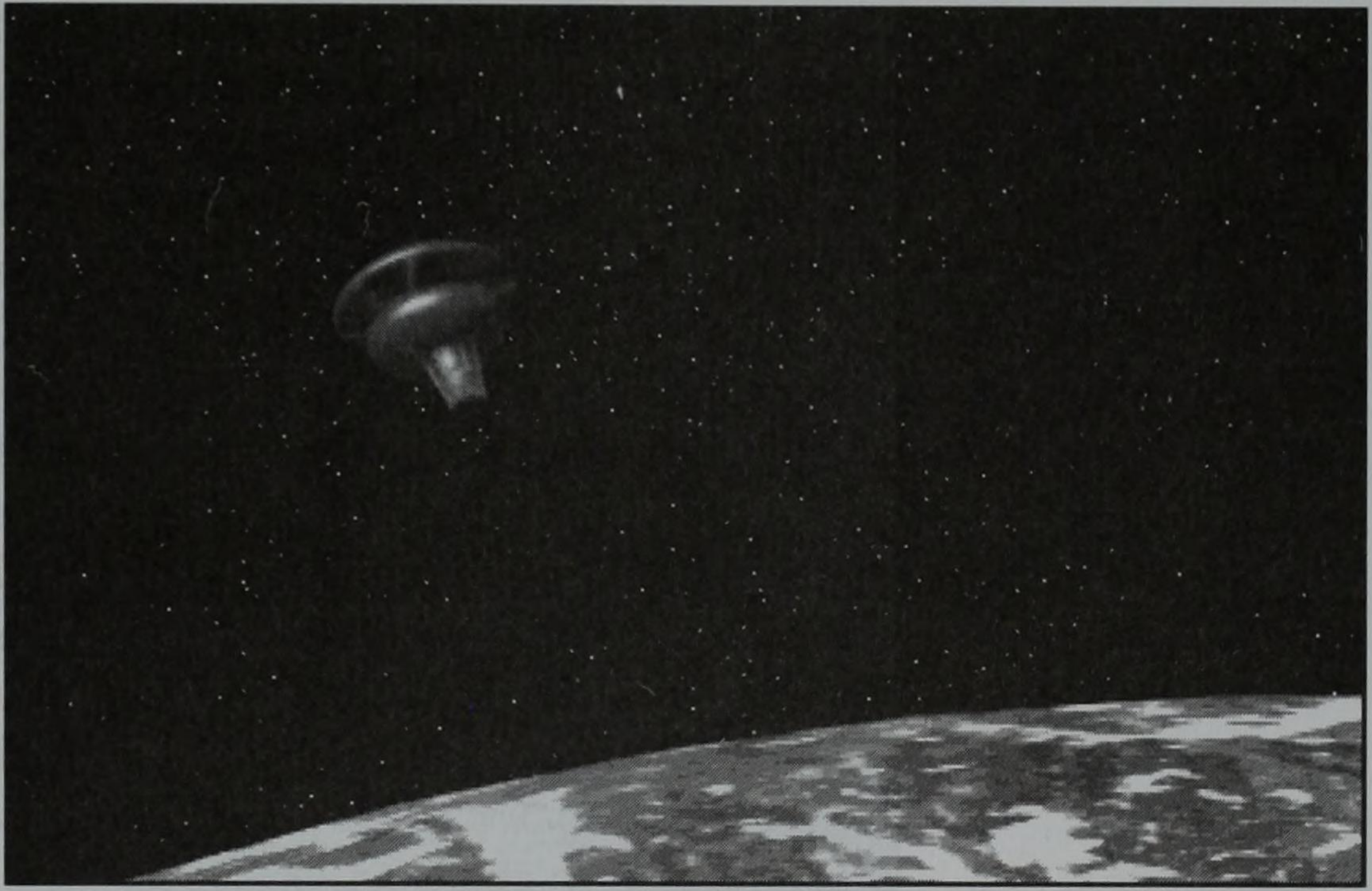
Getting Your Colony Started

When you arrive at your new planet, the starship will enter a stable orbit, as shown in Figure 5-3. Remote planetary sensing will begin immediately so that the AI can help you locate the best landing site. There can be up to 25 landing sites on a planet with a low Hostility level. On planets with a high Hostility rating, there may be only one possible landing site.

The AI will assist you in launching your orbital satellites and planetary probes. This is your opportunity to launch all that hardware you hauled along with you on the trip, so anything you forget to launch now will remain in the cargo area until the entire ship

Figure 5-3

Starship arrival

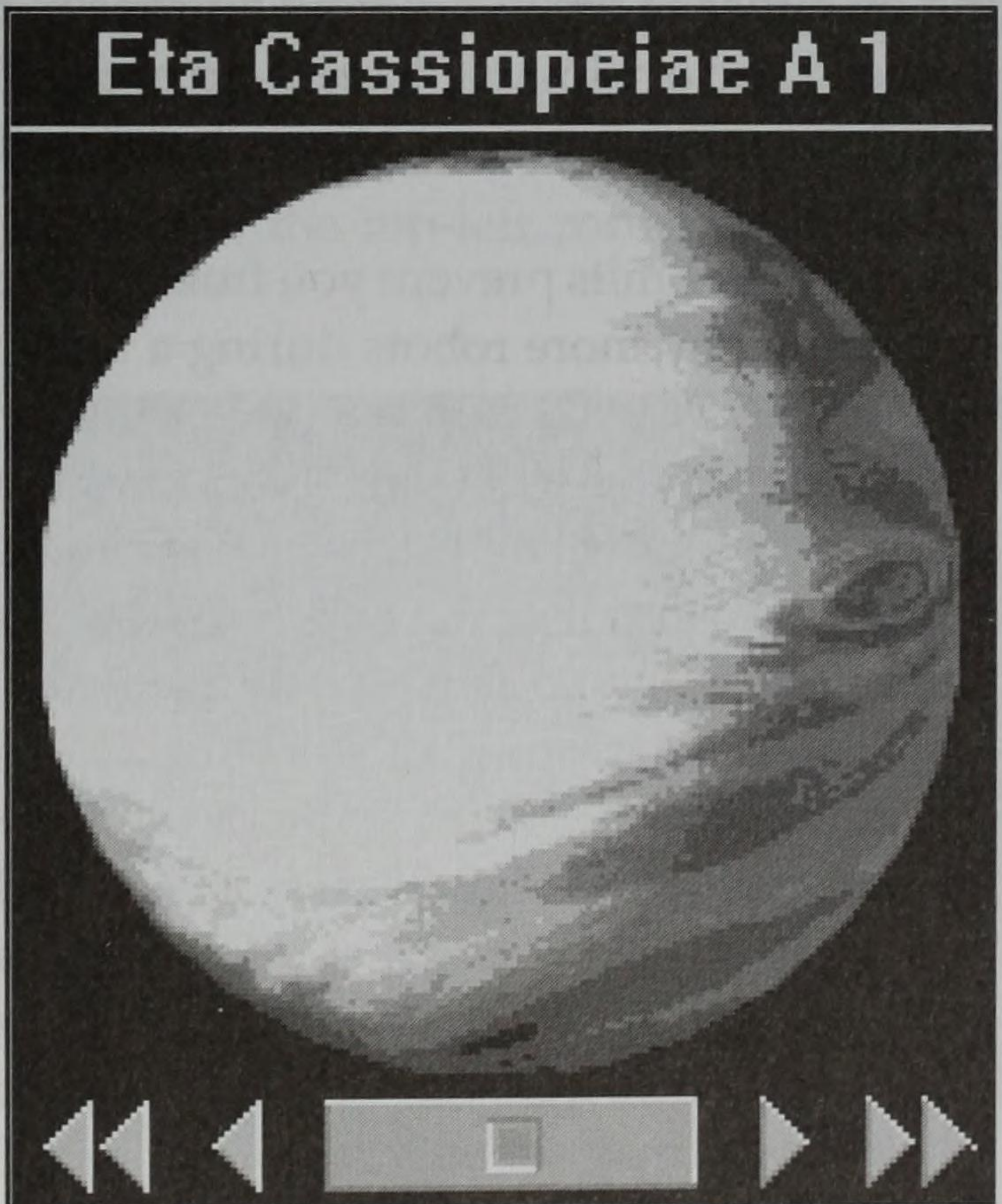


deorbits and crashes into the planet. You're really going to feel like a fool if that happens, and your colonists will think so, too.

When the rotating Planet Display window, shown in Figure 5-4, appears in the top-left corner of your virtual environment, you'll

Figure 5-4

Planet display window



see some controls beneath it that look suspiciously like those on a tape recorder or videocassette recorder. Clicking on the double Arrow buttons will make the planet rotate forward or in reverse. Clicking on the single Arrow buttons will rotate the planet a small amount to let you examine sections of the surface.

Clicking on the large center button will stop the planet and show you the possible landing sites selected by the AI. These landing sites, outlined by rectangles on the planet's surface, have the best geography, potential mining locations, and environment for colony placement. Choose a landing site by clicking on one of the rectangles. This will be the location of your first colony.

While we're still in the Planet Display window, a right mouse click within the window will make a small dialog box appear. Click on the Name option, then replace the default planet name with one of your own choosing.

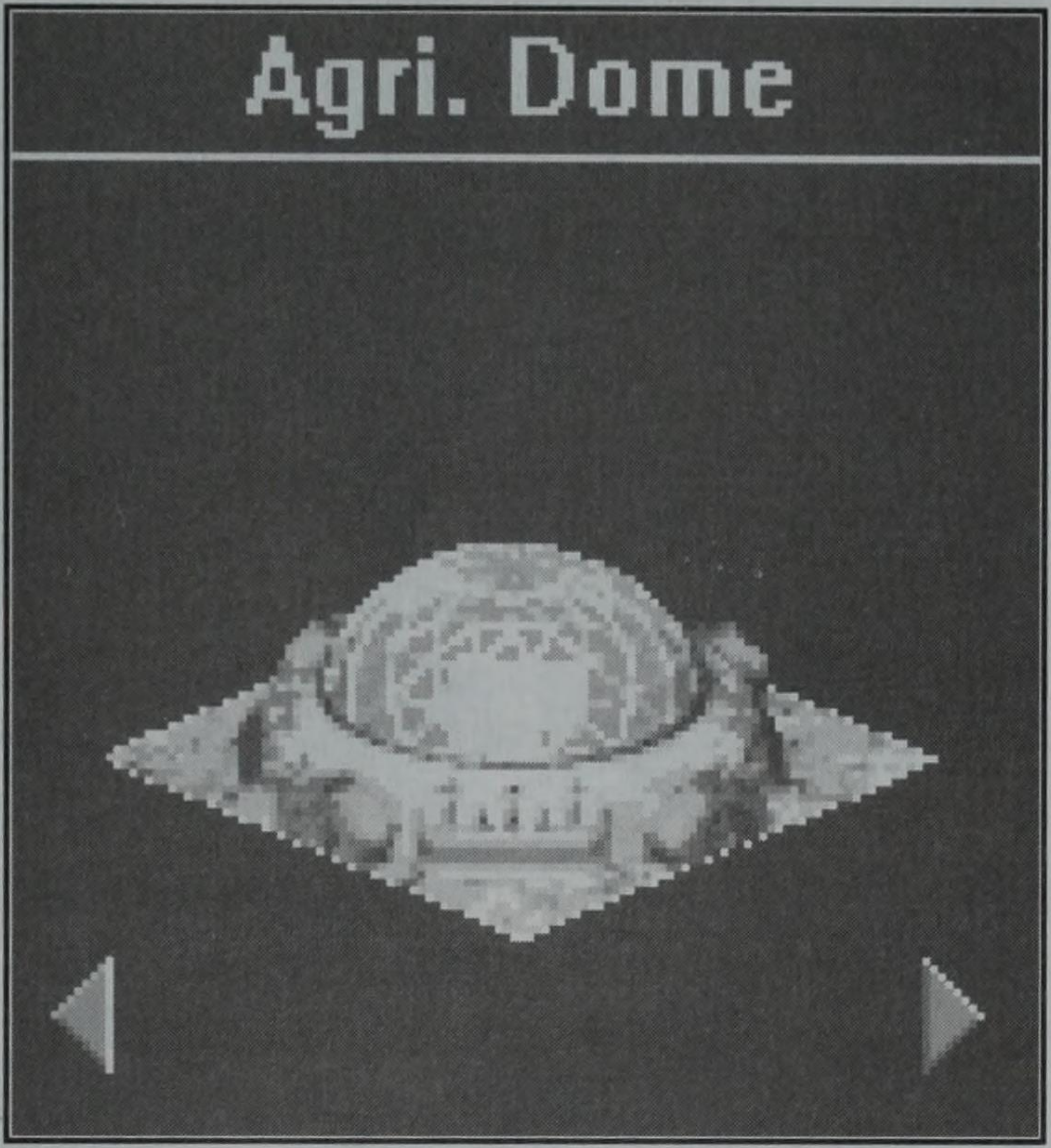
When you selected a landing site, two more windows were generated along the top of the screen, as you can see in Figure 5-1, which is from a later stage of the game. The window in the middle, which we call the Tile Picker, now shows your Seed Factory tile, which you can verify by reading the text at the top of the window that says: "Seed Factory." If there were other structures or landers available, you would be able to scroll through the list by left clicking on either of the two Arrow buttons in the window just below the Seed Factory image. A close-up of the Tile Picker window, displaying an Agricultural Dome later in the game, is shown in Figure 5-5.

When your limits prevent you from building any more structures or placing any more robots during a turn, the scrolling arrows in the Tile Picker will disappear, this window will remain dark, and the text at the top will read: "None Available." If you left click on the dark window, we'll have to assume that you aren't paying attention, so you'll get an appropriately demeaning text message. Let's all try to avoid that embarrassment.

The top-right window shows your chosen landing area, from an orbital perspective, with some of the potential mining locations indicated as red diamonds. This is the landing Site Map, shown in Figure 5-6 (see Figure for Site Map symbols). You'll be seeing a lot of it during the game. A right mouse click on the landing Site Map will show you a *false color* Elevation Map. Another click will return you to the normal view. The text at the top of this window identifies the landing site by number, such as "Site 1." If you'd like to give

Figure 5-5

The Selector window (or Tile Picker)



this landing site a more original name, a right mouse click within the window will make a small dialog box appear. Click on the Name option, then replace the default site name with one of your own choosing.

When you spot a good location for your new colony on the landing Site Map, between a group of mine locations or beside a single mine, left click on that spot. The small square box that was hanging out in the top-left corner of the landing Site Map will now

Figure 5-6

Site Map

The Site Map uses the following symbols during the game:
Red Diamond, Inactive mine;
Yellow Diamond, Active mine;
Bright Blue Triangle, Rebel colony;
Light Blue Dot, Seed Factory.

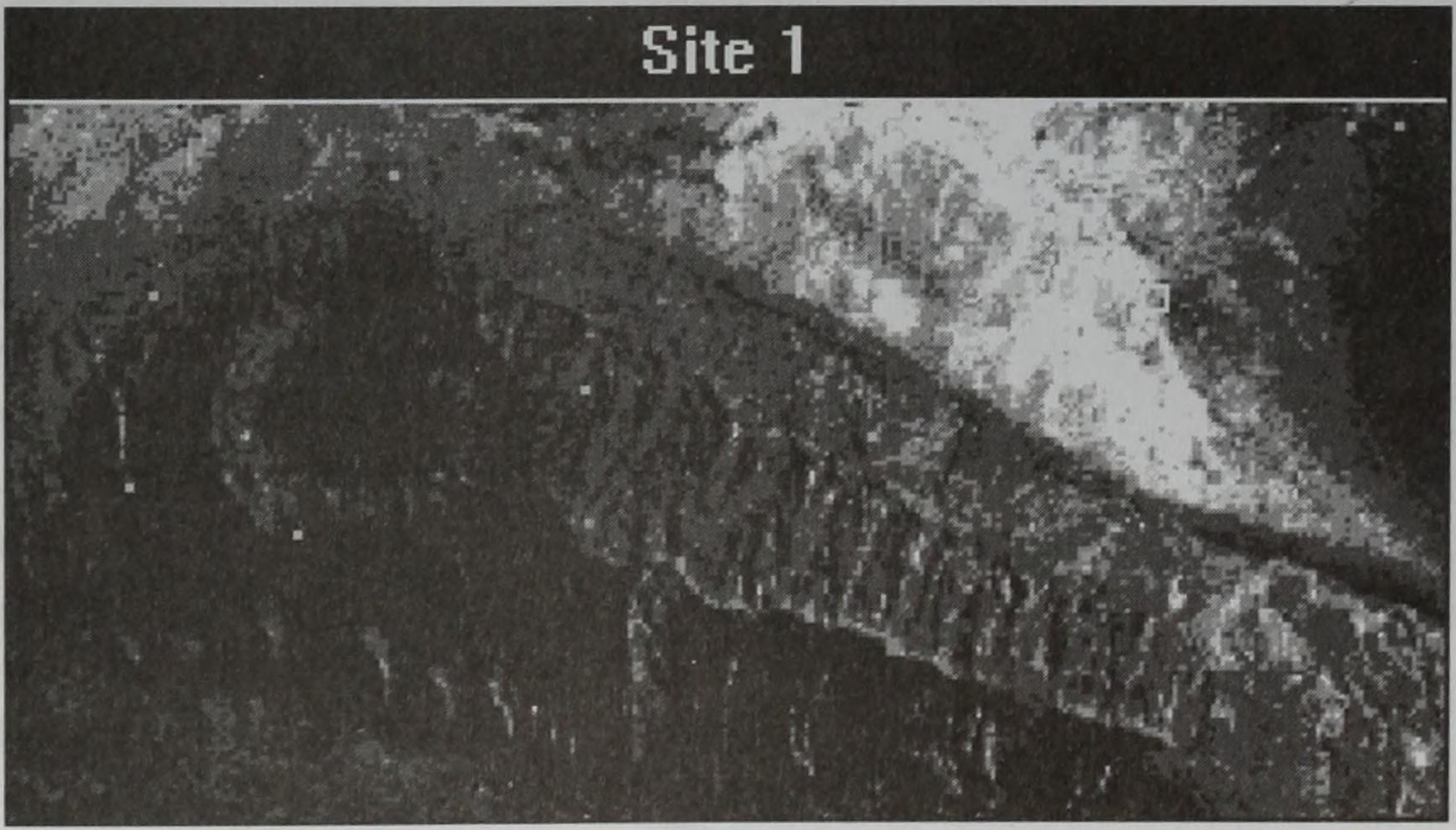
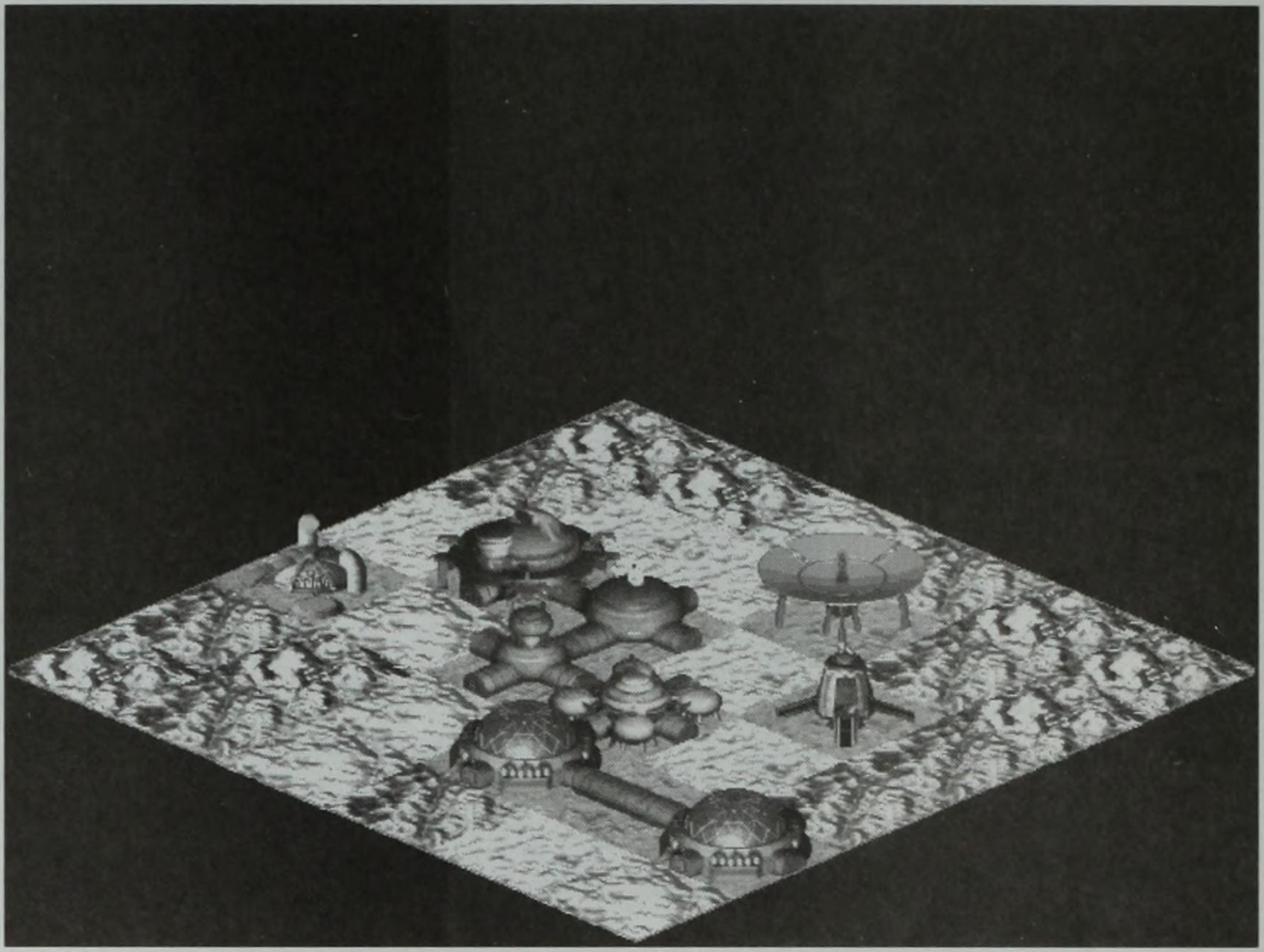


Figure 5-7

Tile Map



move to that location. The diamond-shaped Tile Map, shown in Figure 5-7, takes up most of your screen and displays the specific area highlighted on the landing Site Map by the small square.

The four arrows along the edges of the Tile Map, shown in Figure 5-1, are for scrolling, so that you can fine-tune your tile placements after making big jumps on the landing Site Map. The red scrolling arrow on the top-right edge of the Tile Map indicates north on the Site Map. The Tile Map will be where you spend most of your time in the game, because it shows the structures you've built or are currently building, as well as the local terrain. Red mining beacons on the Tile Map indicate potential mines that have not been excavated.

When you think the local terrain looks suitable for building, click on the Seed Factory in the Tile Picker window at the top of your screen. Your arrow cursor will change into a diamond-shaped cursor to indicate that you've selected the Seed Factory and need to place it on the Tile Map. As long as the terrain on a Tile Map location is not impassable, you can click the diamond cursor on the location and the Seed Factory will land there.

At the lower right corner of the screen is the Completed Turn icon, shown in Figure 5-8, which looks like a featureless planet with a small moon in orbit around it. When you left click on this

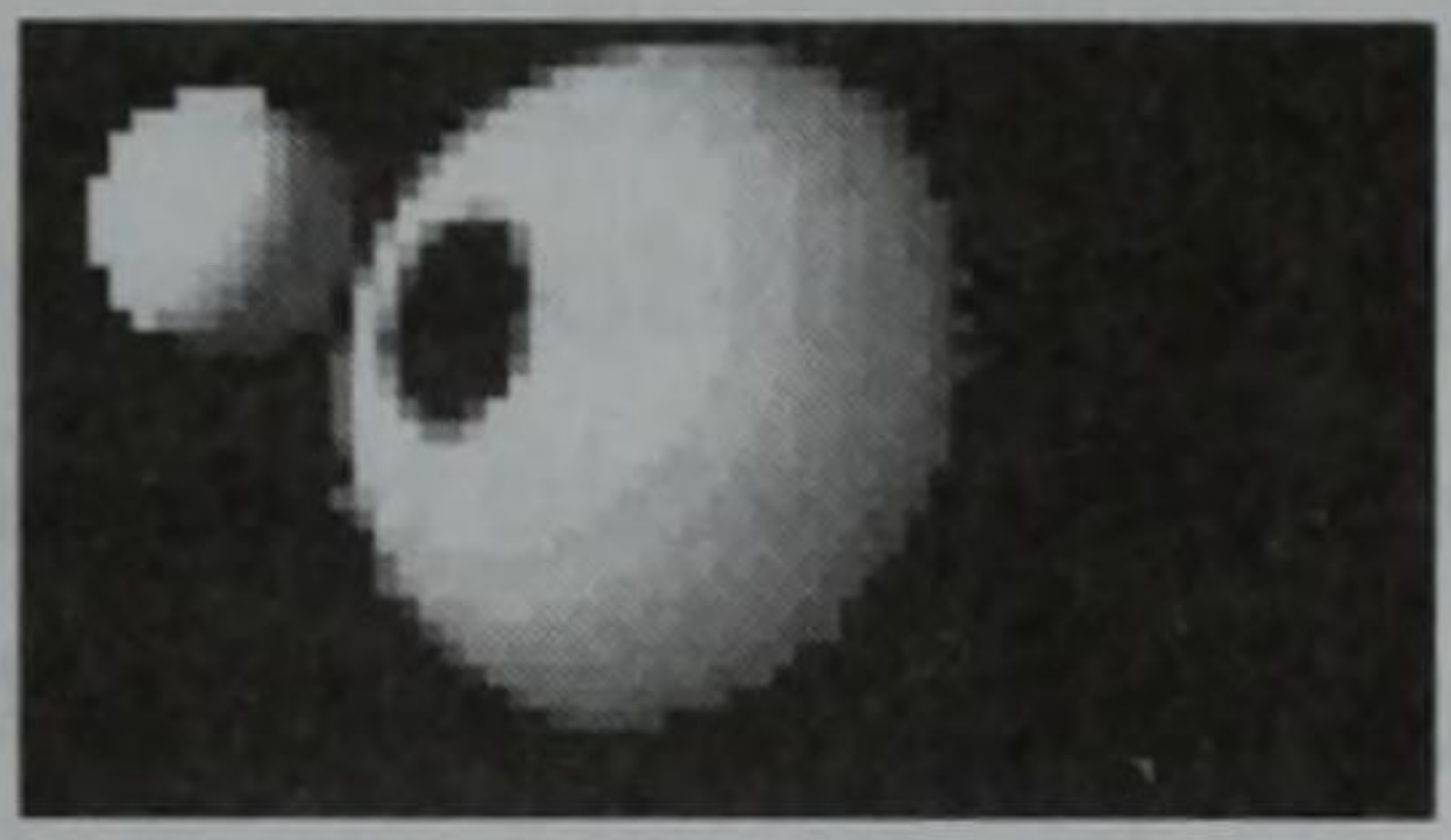


Figure 5-8

Completed Turn icon

little planet, the moon will make one complete orbit and a numbered turn counter will appear next to it so that you'll know which turn you're on. Once the Seed Factory has been placed on the Tile Map, slowly click twice on the Completed Turn icon to process two turns, after which the Seed Factory will start building some new structures.

Details on the Seed Factory and its operation are given in Chapter 6, but here's a brief description of what happens when you land. The ramps come down from the ship and four robots—an explorer, a robominer, a robodigger, and a robodozer—leave the Seed Factory. The explorer seeks out new mining locations, as shown in Figure 5-9. The robodigger starts digging the underground level of the colony. The robominer gathers local raw materials and returns them to the factory. The robodozer clears terrain and prepares it for building.

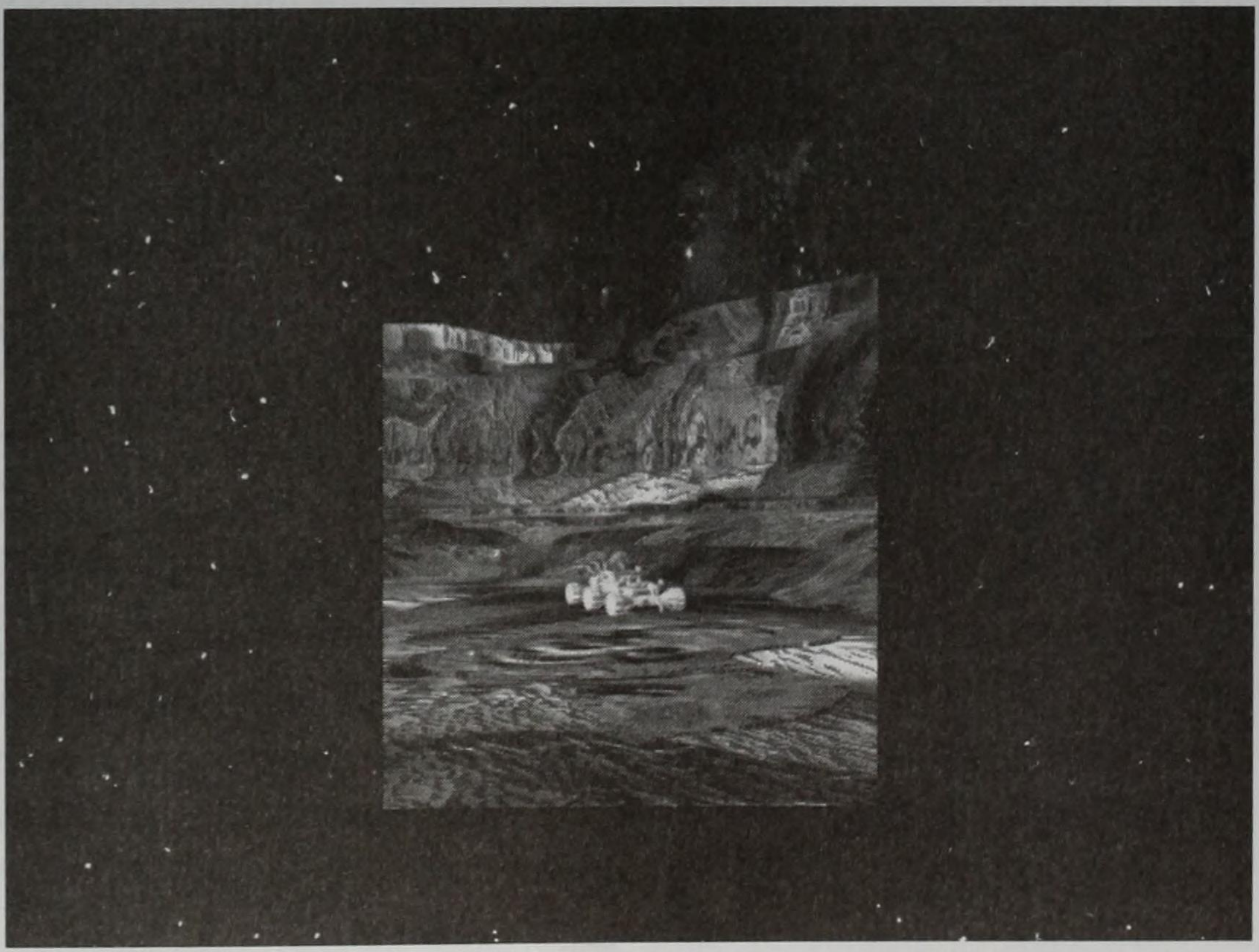


Figure 5-9

Explorer robot

The mined raw materials are processed, using a small smelter and microwaved power beamed down from the orbiting starship, to create more Seed Factories next to the original. This replication increases production capability and allows the new factories some degree of functional specialization.

The raw materials are also used to build a Command Center beside the Seed Factory. This Command Center will be the temporary home for your colonists when you bring them down from the starship. A left mouse click on the Command tile will also show you the Executive Summary Report (use "Reports Are Your Friends," below). Once the Seed Factory has built the Command tile, you need to land your colonists before you can do any further building.

The AI will assist you in launching the cargo landers and colonist landers from the starship. These landers will appear in the Tile Picker window when they're ready to settle down on the surface. Click on a lander to select it, then place it on the Tile Map near your other structures. As each lander touches down, its cargo or colonists become available for use by the colony.

After a SPEW (Sewage Processing and Environmental Waste) Facility has been built later on, the cargo and colonist landers can be bulldozed and recycled into useful resources.

After the colony has a good start, you can instruct the portion of the Seed Factory assigned to robot building to create more robots of a specific type. This robot production capability allows the Seed to operate as a limited robot factory until it eventually fails.

When your colonists have landed, you can start building more structures. Before building anything, the robodozer is placed on that terrain on the Tile Map to prepare a smooth area for construction. The time it takes to clear the terrain depends on the difficulty of the terrain (you can't place a bulldozer on impassable terrain). In the early stages of the game, you'll find yourself clicking on the Completed Turn icon a lot as you bulldoze terrain and build structures.

After your Seed Factory has replicated itself and built a Command Center, and your robominers are robomining, and your robodozers are robodozing, and your colonists have landed, you'll be presented with more structures you can build. The Seed Factory has prepared the way; now it's your turn to start making some practical building decisions.

Your colonists need to eat, breathe, use power, build necessary facilities, and build protected residential areas as soon as the robo-digger has cleared out enough area underground. Mined resources are necessary for most structures. You can vary this list somewhat, but the next structures you build should address these needs in the order just listed: Agricultural Dome, CHAP (Closed Habitat Atmospheric Production) Facility, a power generation facility, Storage Tanks, and Residential units.

Beyond the basic, self-contained structures, you will also need to remember that Tube connections are necessary before new construction can begin.

Starting More Colonies

If your first colony has become self-sufficient, and you've decided to develop several smaller colonies rather than one gargantuan colony, there is one basic procedure to follow.

Once you've located a suitable site for your new colony, preferably near a mine and over 30 tiles away from any other colony, place a Command Center. Placement of a Command Center tells the simulation that a new colony has been established and that all construction near the new Command will belong to that colony. This becomes quite important when colonies start to overlap and the simulation has to figure out how to distribute resources each turn.

Resources will be a problem when starting a new colony. When your Seed Factory landed, it had smelter and power facilities onboard that are no longer available to you. Establish new mines as quickly as you can, but processed resources for building and maintenance will have to be delivered by truck or monorail. Mined ore will need to be processed by a local Smelter for efficiency, so this will be one of your early building goals. As is true of the Command tiles, Smelters are self-contained, so they can be built without Tube connections to power supplies or air. Remember that processed resources must be transported to local Storage Tanks to become available for use by that colony, so these must be built before the Smelter.

A Matter of Time

Time is measured in game turns. This is true in *Outpost*, but there are those who apply this to real life. Maybe you've met one of these people. Maybe you're one of them. The point is that this is not what is known as a "real-time" simulation. Time will not advance until you click on the Completed Turn icon (or press Ctrl-T if you're a keyboard user). To run a large number of turns, use the 5 key and enter a number. If you sit there and stare at your computer without running a turn, time will stop on your planet until you use your omnipotent powers to make it move again.

Why can't the game run by itself? Why can't the colonists just lead their lives without any interference from you? If you're asking yourself these questions, I'm worried about you. Seek help before it's too late.

The problem I see with real-time simulations is that they depend more on your quick thinking than they do on careful planning and strategy. *Outpost* is for the player who wants to think about a decision before taking action. This is the sort of person who figures out how to pause a real-time simulation so that they have time to think about what they're doing.

If you're one of those people who prefer the urgency of a running clock and deadlines rushing toward you, play *Outpost* in front of an oncoming train. If you're the sort of highly evolved life form that prefers strategy games, you've come to the right place.

How to Make Your Life Difficult

Whenever you start a new game, you will be asked what difficulty level you would prefer. There are a variety of internal conditions that check your chosen difficulty setting before making a decision. Planetary Hostility effects, exchange rates during trading sessions, the amount of help you get from the AI adviser, damage from disasters, and a variety of other variables that are listed in the game manual are adjusted according to your chosen difficulty setting.

Your first time through the game should be played at the default Easy level, which will give you time to learn the game mechanics and how the simulation responds to your personal strategies. The Medium level of difficulty will make a noticeable difference in the simulation's responses. When you select the Difficult level, you're telling the game that you think you can beat the pants off of it with a stick from 20 yards away, so be prepared for a tough encounter without any consideration from the simulation.

Where to Find Help

All help is given through the artificial intelligence (AI), who is always hanging around at the lower left corner of your main Game screen while the simulation is running. During the targeting, packing, and travel phases at the beginning of the game, the AI can still be reached to give help when needed, but the Chrome Ball icon won't always be there until you've landed on the new planet.

A left mouse click on the Chrome Ball icon, shown in Figure 5-10, will summon the AI, who will present you with a list of options. These options include Help. A right mouse click on any part of the main Game screen, when the Tile Map is displayed, will also give you a dialog box with a context-sensitive Help option. Context-sensitive Help will send you directly into the portion of the Help system that relates to the part of the screen you clicked on.

A Click to the Right

The options available to you through right mouse clicks on the main Game screen are described in detail in the game manual. These options vary depending on the window you're right clicking in, but they give you access to Windows functions, file functions, game control, Tile Map display levels, preferences, and the context-sensitive Help option.

Construction Sites

When a building is under construction, it will usually be represented on the Tile Map by the framework of the building surrounded by work lights. A close-up of a typical construction site is shown in Figure 5-11. If you run out of resources before the building is complete, this construction tile is all that you will ever see unless you bulldoze the site and start over again. If you run out of resources, your colonists assume that you weren't serious about erecting that building, so they just forget about it. If resources continue flowing into the construction site, the building will be completed after the appropriate number of building turns, replacing the construction tile with the final structure.

Figure 5-10

Your artificially intelligent helper

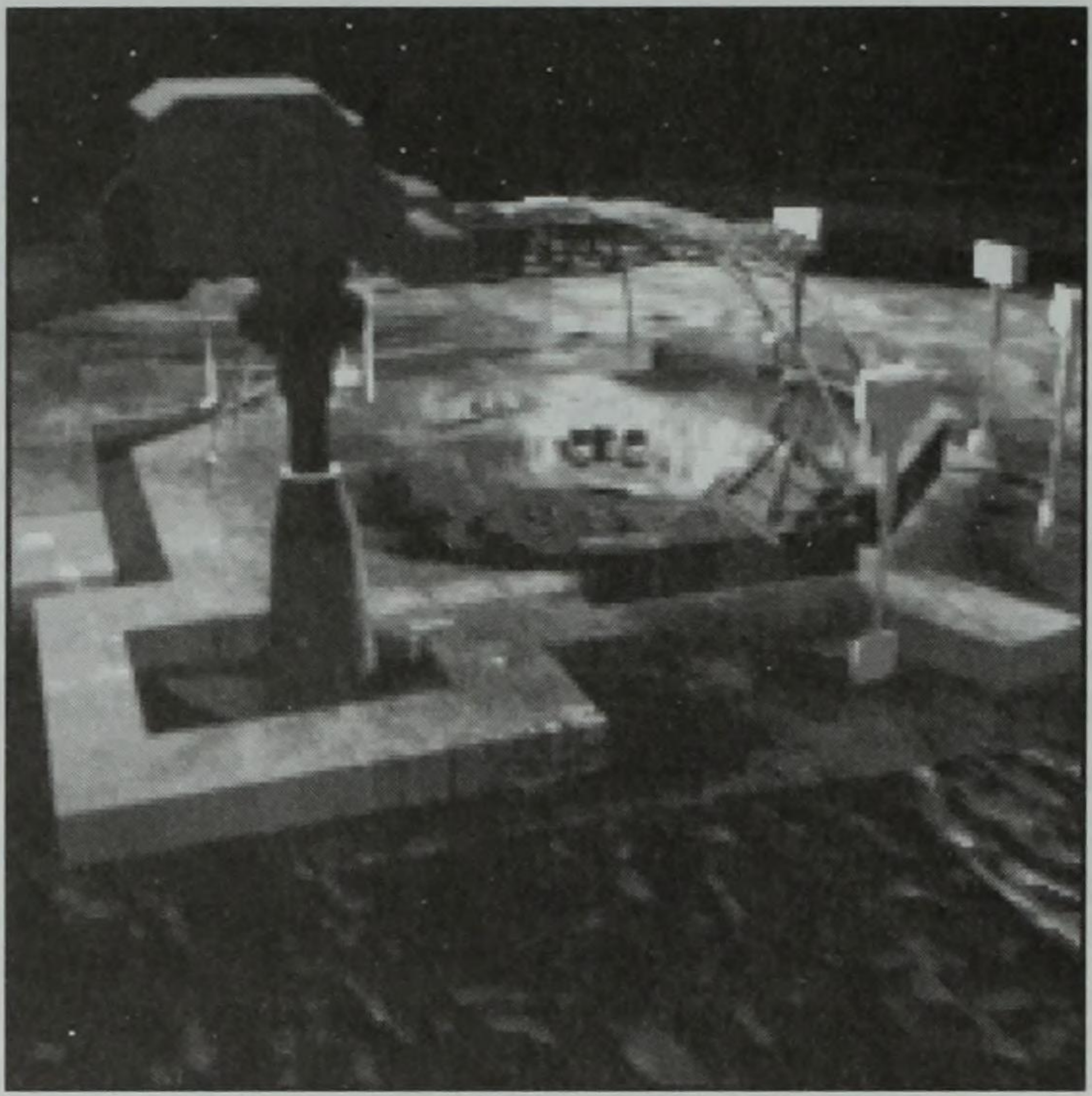


Figure 5-11

Construction site

Reports Are Your Friends

To keep you up to date on the changing conditions within your colony, your AI will maintain a variety of reports that you can refer to at any time. A left mouse click on most buildings will give you a report specific to that facility. These include individual mining reports, factory production summaries, warehouse and resource storage reports, and laboratory research reports. Laboratory reports also give you access to the research tree so that you can determine the direction of an individual laboratory's research efforts. Details of these reports are given in the game manual.

If you just want an overview of what's happening, the Executive Summary Report, available from the Command Center, or through the AI adviser, will show you such things as the total number of active mines, the current pool of available resources, how many laboratories are performing research, how many Agricultural Domes are producing food, and so on. The Executive Summary Report also has a Detail button under the Population entry, from which you can see a breakdown of your population categories.

When you have reached a sufficient level of complexity, and you have multiple AI managers available for handling administrative tasks, you will also have access to a Macromanagement Report through your AI adviser. This report gives you overall numbers for each of your colonies and allows you to reallocate your AI managers as well as their administrative tasks.

Terrain Types and What They Mean to You

As you would expect in real life, the surface topography on a landing Site Map corresponds closely to the geological features you see from orbit on the Planet Display window. These primary features range from rocky and icy to cratered and frozen. They can also show evidence of ancient or recent volcanic activity. A right mouse click on the Site Map summons the Elevation Map, indicating surface features in a false color display with four different colors.

On the Tile Map, which is a close-up view of an area of the Site Map, terrain types affect the speeds at which your robots and machinery will operate. Surface terrain consists of five basic types: clear, rough, hostile, impassable, and dozed. Travel times over these terrain types are given in Chapter 11. Underground terrain consists of four basic types: easy, difficult, impassable, and dozed. Above and below ground, "dozed" means that a robodozer has worked on that tile and created a building pad suitable for further construction. Impassable means you can't build on it, mine it, or dig it, so just forget about it.

The base values used to calculate bulldozing, mining, and digging times will give you a vague idea as to how long it will take to perform such actions on specific types of terrain. These base values are modified according to the difficulty level you chose for the game, the hostility of the planet, and other factors such as the phase of the moon and how my lead programmer felt on a particular day.

Surface bulldozing will be completed in one game turn on clear terrain, two turns on rough terrain, or three turns on hostile terrain. Underground bulldozing will be completed in two turns on easy terrain, or three turns on difficult terrain.

Surface mining and digging both use a base value of three turns for clear or dozed terrain, four turns for rough terrain, or five turns for hostile terrain. Underground mining and digging use a base value of four turns for easy terrain, or five turns for difficult terrain. However, mining and digging times are figured by adding the difficulty of the starting terrain to the difficulty of the destination terrain, so the total base value for time required will range between 7 and 10 turns. This value is then modified by other factors.

The moral of this story is that you should allow plenty of time for mining resources.

Advice from an Artificial Intelligence

Many people might think of asking an artificial intelligence for advice as being similar to asking your toaster oven who you should marry. With current technology, that would be an accurate statement. With *Outpost* technology, you have nothing to fear... unless you're talking to an unstable AI personality,as described in Chapter 15.

The most direct method for reaching your AI adviser is to left click on the Chrome Ball icon that sits around in the lower left corner of your screen below the Tile Map. When you wake it up like this, the AI will present you with a menu of helpful options. Not only will it provide you with extensive Help files about the game, but it will handle diplomatic and trade matters, the naming of large objects such as your planet and your colony, electronic news briefs, alerts about upcoming disasters, and phone calls from insurance salesmen. Your AI can also perform a variety of administrative and research tasks without soaking up a salary or requiring food.

Is there anything your AI can't do for you? Well, I still wouldn't ask it who you should marry. Try asking your toaster oven.

I Thought I Told You to Shut Up: No-Frills Gaming

When you start the game, you're allowed to set your preferences. The default dialog box, which you can reach with a right mouse click from most of the main Game screen when the Tile Map is displayed, has a "Control" selection. When you left click on Control, you are tossed into a smaller menu where one of the options is "Preferences."

A left click on Preferences will hurl you into a special dialog window where you can turn animated sequences off, let them run all the time even if you've seen them before (the default), or make them play only once. When we say animated sequences, we're referring to the little movie segments in the introduction, and to the cutaway segments that illustrate events or discoveries during the game. From this Preferences box, you can also turn the tile animations on or off. The tile animations are the movements on the tiles themselves that give life to the colony's appearance. On the slowest of computers, any movement on the screen can slow things down even more, including the tiny tile animations. Of course, we'd prefer that you see the game on a faster computer so that you can experience all the performance capabilities of the game, but we have to be realistic about it.

While you're still in the Preferences box, you can also decide whether to turn the music on or off, turn the sound effects on or off, or view the familiar Windows title bar during the game (the default hides the Windows title bar). We are, of course, quite pleased with our sound effects and music, and would prefer that you leave them turned on, but if you've already heard it all a thousand times, it could become tiresome. It's up to you. Really. It's your game. Don't feel like you owe the development team anything, just because they spent over a year of their lives pouring blood and sweat all over their computers to produce *Outpost*. Sure, just sit there and pass judgment on us just because...oh, sorry, got a bit carried away there.

This ends the tutorial chapter. I've given you enough information to sit down and get your colony started without feeling completely lost in the type of obscure interface that game designers are so fond of creating. Okay, maybe it's not so obscure. In fact, we tested and adjusted the interface for playability long before the game was released, just because that's the kind of people we are. I've also told you where to find more help and how to shut off the extra features that can bog down a slow computer. What more could you ask?

What's that? Did someone say they need more detail on how a Seed Factory operates? You want to know where such a magical device came from? You want me to justify its existence in a realistic game like this? Has anyone ever told you that you're pushy? Fine. Read the next chapter and I'll tell you all about it.

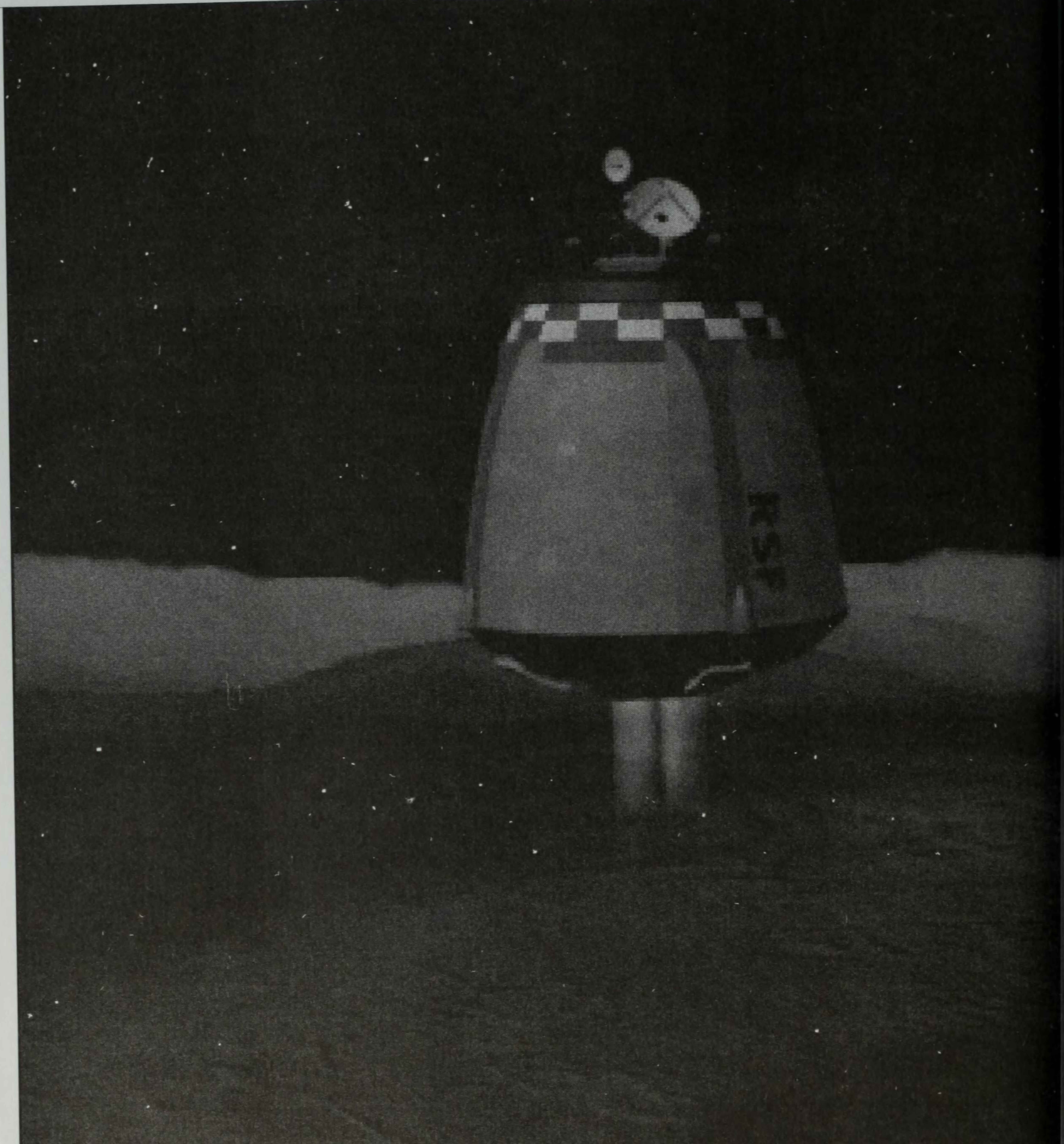
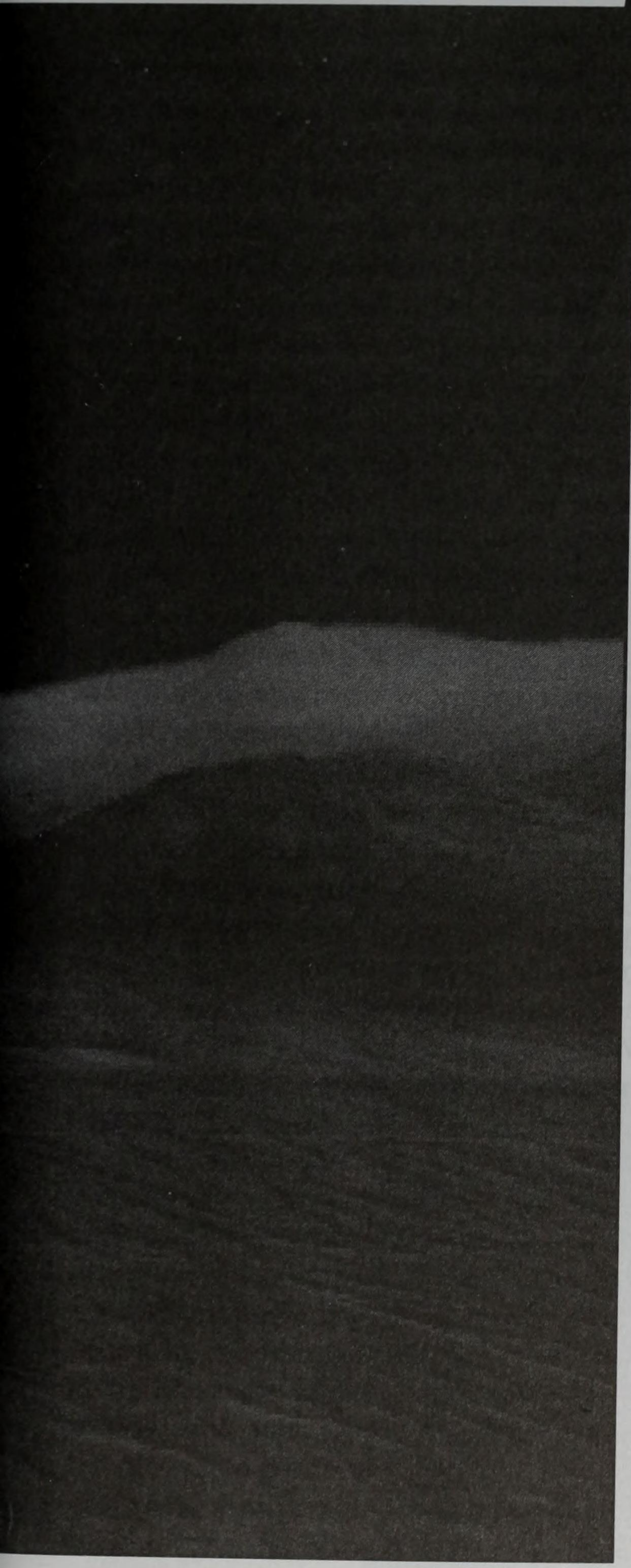


Figure 6-1 Seed Factory landing



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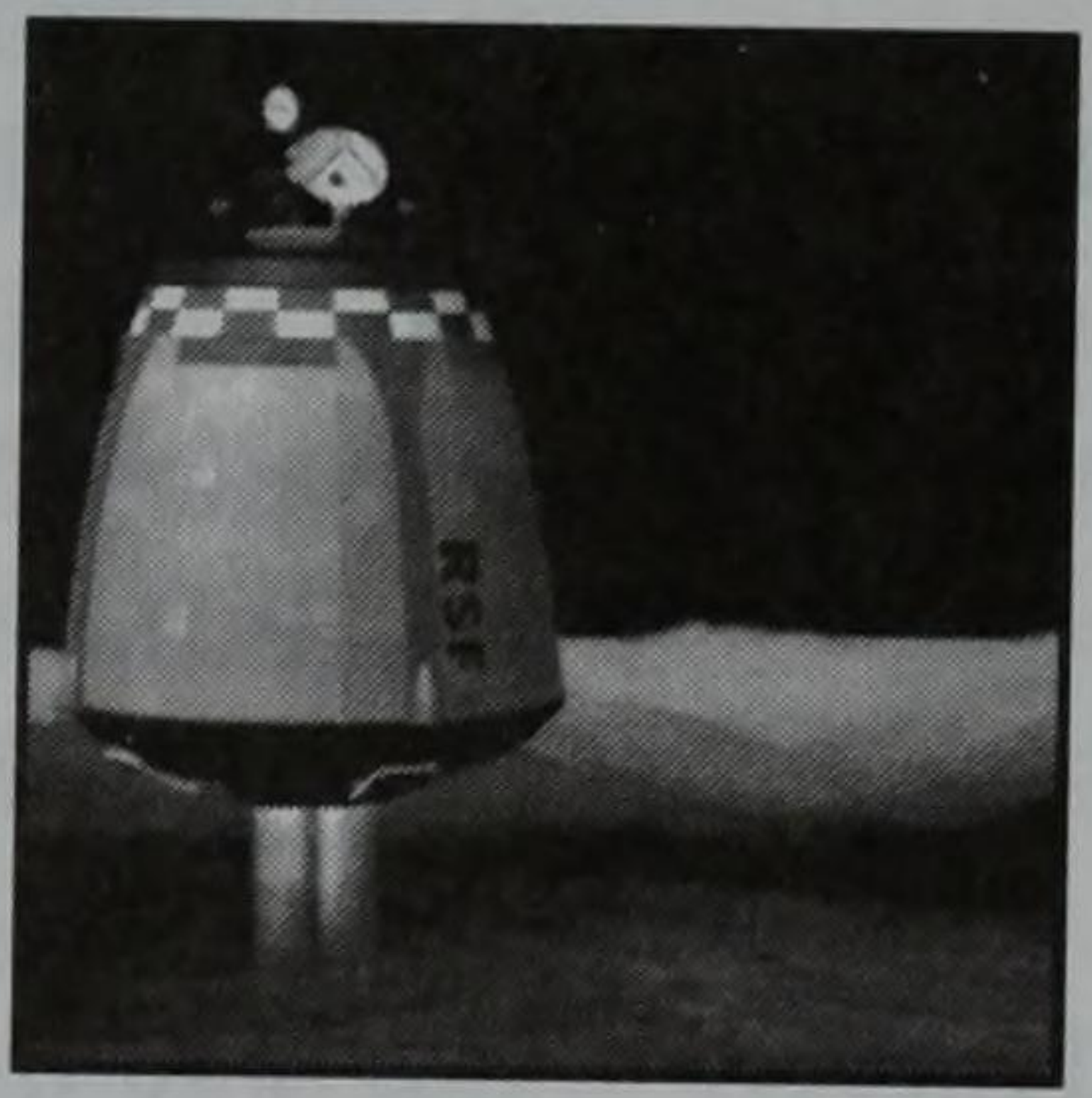


The Seed Factory

To own a bit of ground, to scratch it with a hoe, to plant seeds, and watch the renewal of life—this is the commonest delight of the race, the most satisfactory thing a man can do.

Charles Dudley Warner,
My Summer in a Garden (1870)

Everbody says you need a Seed Factory, you think you ought to have one, but you're embarrassed to admit that you can't tell the difference between a Seed Factory and a hole in the ground. At parties, you nod as if you know what people are talking about, but you hope no one asks you how your Seed Factory is doing because you'd probably try to talk about gardening and you know if you did that they'd realize you're a fraud, they'd point and laugh at you, and your face would turn as red as the punch. Well, if nothing else, this book exists to save you from such social disgrace. This chapter plants the seed of knowledge in your mind, where it will blossom and grow into a metaphor so large that your skull will burst with the flower of wisdom. You might even learn something about Seed Factories, the use of robots in hostile environments, automated factories, telepresence, and how to pave the way for a safe landing by your colonists.

Overview: Planting the Seed

In 1980, NASA and the American Society for Engineering Education assembled an impressive array of scientists to study the proposed use of machine intelligence, including automation and robotics, in future space missions. NASA had come to realize that advanced automatic and robotic devices, using machine intelligence, must play a major role in future space missions. These systems can accomplish tasks that are too dangerous, labor intensive, or expensive for humans to perform. The merger of human intelligence and machine intelligence is resulting in machines with a growing capacity to accomplish important tasks.

Previous studies, at Woods Hole in 1979 and Pajaro Dunes in 1980, recognized that the cost of traditional space operations, even if transportation becomes much cheaper, makes many proposed large-scale enterprises too expensive. Long delays between a large investment of funds and significant returns make the financial burden even less attractive to public and private research sponsors. The highest cost factor involves the apparent need to carry fully operational machinery and equipment to manufacture such things as water, oxygen, or solar cells at the destination. These studies were aimed at determining if certain large-scale projects could be made cheaper and more feasible by using machines able to reproduce themselves from energy and material resources already available at the destination. Such machines could create an increasing number of identical self-replicating factories that could then produce the desired end products. The groundwork for this type of "self-reproducing automata," pioneered by John von Neumann 40 years ago, already exists, although it has never been translated into actual engineering designs or technological models.

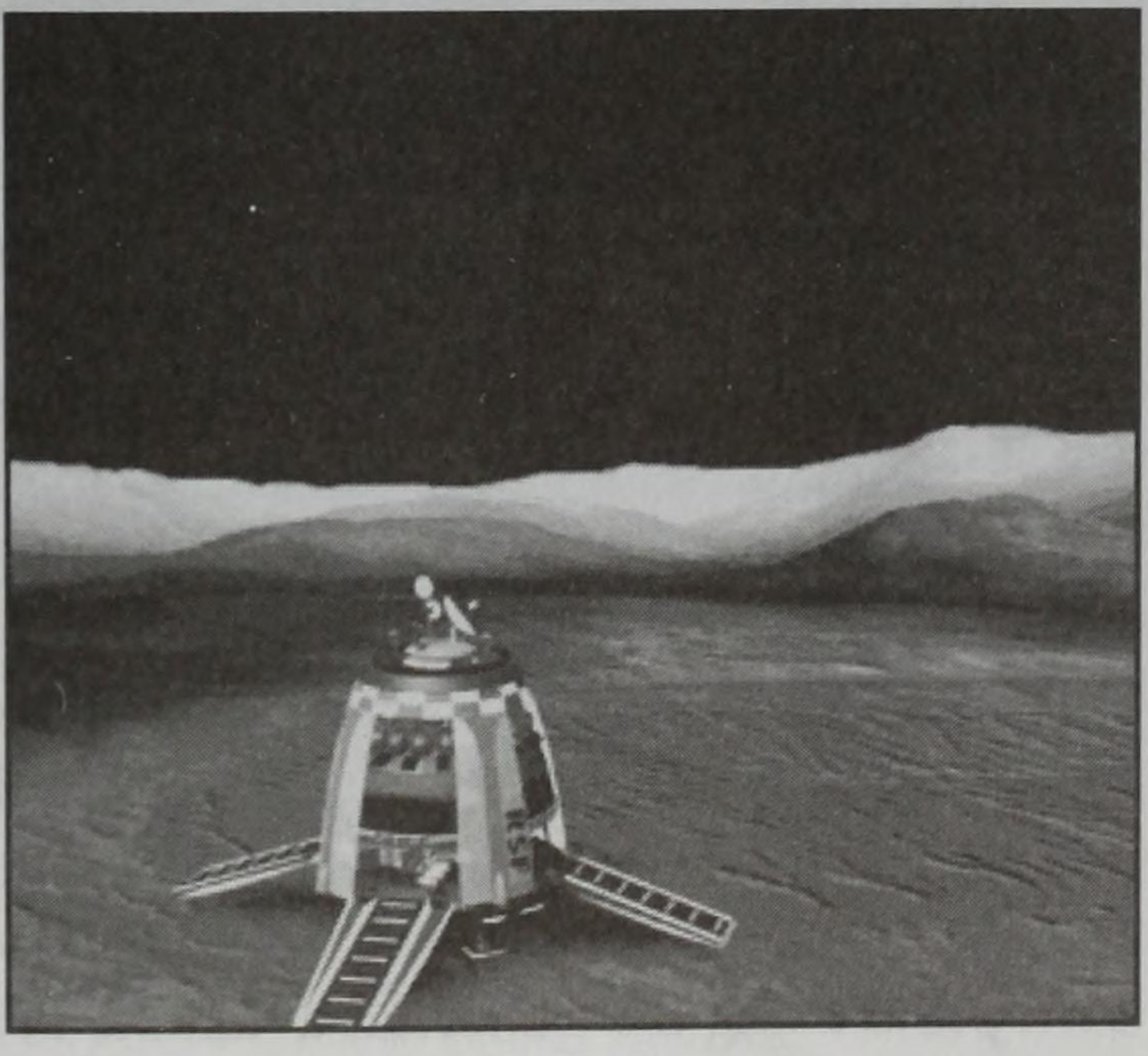
In practice, self-replicating machines might not have to be totally independent. The extensive use of automation, robotics, and machine intelligence, perhaps aided by humans in remote locations through the use of *telepresence*, would make a production system possible that could grow exponentially.

One study focused on the concept of a self-replicating lunar factory, also known as a *Seed Factory*. This would be an automated, unmanned manufacturing facility, as shown in Figure 6-2. It would consist of perhaps 100 tons of the right set of machines, tools, and teleoperated mechanisms to permit both production of useful output and reproduction to make more factories. The study demonstrated that the following six areas of research need to be developed further before a Seed Factory design can be successful:

- **Machine vision capabilities** Especially in the areas of depth perception, multispectral analysis, modeling, texture and feature, and human interface
- **Multisensor integration** Including all nonvision sensing such as force, touch, proximity, ranging, acoustics, electromagnetic wave, chemical, and so forth
- **Locomotion technology** To be used in exploration and extraction processes with wheeled, tracked, or legged devices under teleoperated or autonomous control

Figure 6-2

The Seed Factory begins operation.



- **Manipulators** To be used in handling materials both internal and external to the machine, general purpose and special purpose, teleoperated or fully automatic
- **Artificial intelligence** Including reasoning, logical deduction, plausible inference, planning and plan execution, real-world modeling, and diagnosis and repair in case of malfunction
- **Man-machine interface** Including teleoperator control, kinesthetic feedback during manipulation or locomotion, computer-enhanced sensor data processing, and supervision of autonomous systems

Von Neumann Started It

As mentioned previously, the idea of a machine reproducing itself is not new. The mathematician, John von Neumann, was the first to wrestle with the idea of machine reproduction. Von Neumann described a machine residing in a "sea" of spare parts. The machine's memory tape instructs it to go through certain mechanical procedures, using a manipulative arm and an ability to move around in the environment, and pick up parts to be connected together. The tape program first instructs the machine to reach out and pick up a part, then go through a selection or identification routine to figure out whether the part it holds is the correct part. If not, the part is thrown back into the "sea" and another part withdrawn for similar testing. Having identified a correct part, the machine searches for the next correct part, then joins the two together according to the instructions.

This machine continues following its taped instructions to make something without really understanding what it's doing. When it has finished, it has produced a physical duplicate of itself. The new machine has no instructions, so the first machine must copy its own memory tape into its offspring. The last instruction for the first machine is to activate the second machine.

Von Neumann's logical organization for a kinematic machine is not the only possible answer, but is probably the best and simplest way to achieve machine replication. If the process sounds familiar, it may be because the logic behind it is very similar to the way living organisms reproduce. Of course, this machine dwells in a perfect world where all of its needs are supplied freely through the "sea" of spare parts. Our Seed Factory will have to make its own parts using the materials available at its location.

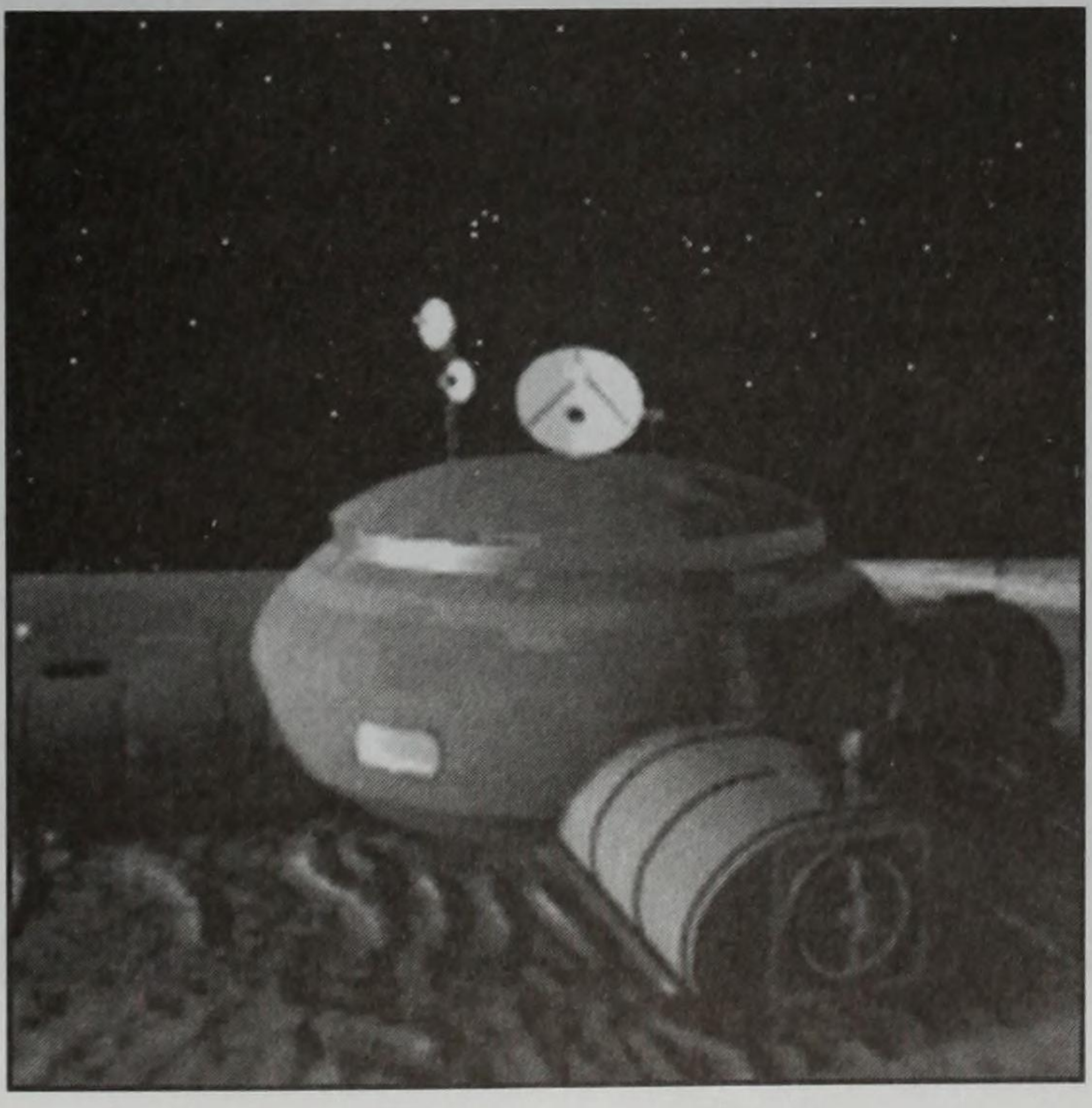
How It Works

The self-replicating Seed Factory design is an automated, multiproduct, remote-controlled, reprogrammable manufacturing facility capable of constructing duplicates of itself that would themselves be capable of duplication. Successive generations of the factory don't need to be exact copies of the original but could, by remote design and control, be improved, reorganized, or enlarged so as to reflect changing requirements. Humans would continue to decide what kinds of factories should be constructed, when new factories are to be made, how many of them are to be made, where they should be sited on the lunar surface, and what kinds and amounts of goods would be produced. These decisions would all be made by remote control.

The initial *Outpost* colony will be established from orbit by dropping an advanced form of this Seed Factory down to the planet's surface from the colonization starship. This factory, described below, will establish a small base of operations with a self-contained environment so that the first humans to land will have a preconstructed shelter to live in while the next structures are built. The shelter will also become the command and control facility for your colony, as shown in Figure 6-3. This factory also generates a limited amount of power to be used by the first few structures built within the colony.

Figure 6-3

Command facility built by Seed Factory



Four major subsystems comprise each Seed Factory:

- **Materials Processing Subsystem** Acquires substances from the environment and prepares industrial feedstock from this material.
- **Parts Production Subsystem** Uses the feedstock to make machines or other parts, which are then sent to one of the following subsystems:
- **Universal Constructor Subsystem** Parts are used to construct a new Seed Factory (replication).
- **Production Facility Subsystem** Parts are made into commercially useful products.

The subsidiary subsystems of a Seed Factory are a Materials Depot, Parts Depot, Product Depot, Command and Control, and an Energy System.

The initial Seed Factory would expand into two identical halves, each of which would have three major sectors:

- **Chemistry Sector** Accepts raw soil, extracts needed elements, prepares process chemicals, and refactories for use in the Fabrication Sector.
- **Fabrication Sector** Takes in elements and compounds in powdered or gaseous form, then manufactures parts, tools, and electronic components.
- **Assembly Sector** Assembles fabricated parts into complex working machines or useful products of arbitrary design.

Subsidiary functions to the Seed Factory would be served by bulldozing robots, mining robots, automated transport vehicles, warehouse robots, machine assembly and repair robots, computer control and communications, and the photovoltaic solar canopy to provide electrical power for the system.

Ore Processing

The technology required for the Seed Factory to process nonterrestrial materials on another planet does not yet exist. Processing methods such as electrolysis, hydrogen fluoride leaching, and carbochlorination are adequate for short-term use but would be unable to meet long-term growth demands. Processes must be developed that yield a broad range of elements and materials, including fluorine, phosphates, silica, and many others. Volatiles such as water and radon, and desirable rock types such as alkalic basalts, could be acquired as a result of planetary surface exploration. High-grade metals would have to be mined or retrieved from local asteroids.

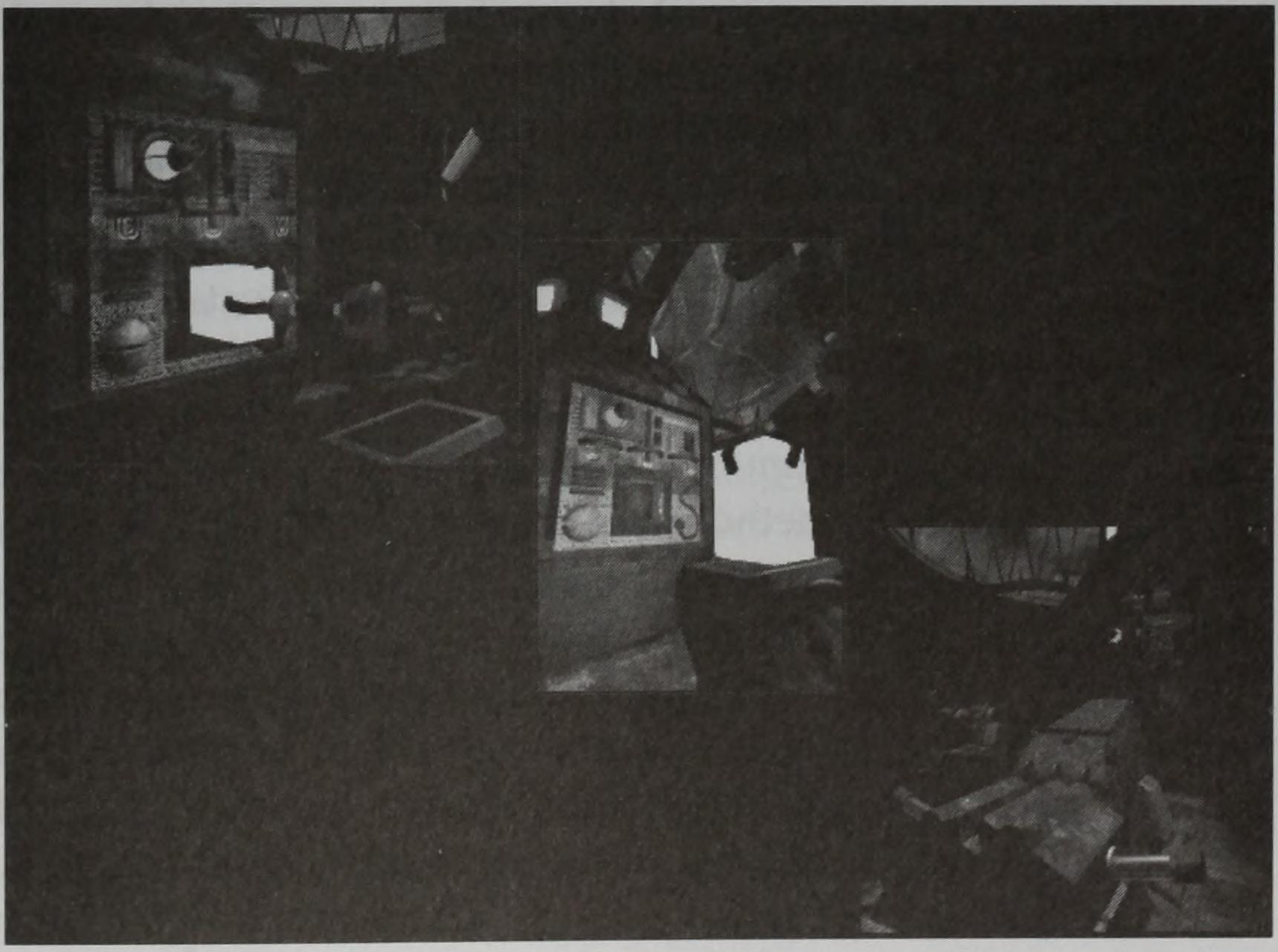
To supply the required feedstock and chemicals to the Seed Factory, automated chemical, electrical, and crystallization techniques must be developed. New oxygen-based chemical processing methods are being studied to meet this demand.

On-Board Factory

The Fabrication Sector of the Seed Factory, shown in Figure 6-4, involves two general formation operations. *Primary shaping* involves turning the raw material into the approximate size and shape of the intended machine part. *Finishing* refines the basic shape into its final form. The most promising primary shaping technologies for space manufacturing are casting and powder processing techniques. With proper control, both methods produce parts ready for use without further processing. Casting techniques appear more versatile in terms of the range of materials—metals, ceramic, metal-ceramic—that can be shaped, but powder processes may outperform casting for metallic parts.

Figure 6-4

Fabrication in operation



Assembly requires robotic/teleoperator vision and end effectors that are smart, self-preserving, and dexterous. Fastening technologies, including non-volatile adhesives, cold welding, mechanical fasteners, and welding would all require special adaptation to the environments of other worlds.

Control of a large-scale Seed Factory demands the use of a distributed artifically intelligent information system. Material handling tasks require automated mobile robots/teleoperators. To support these activities, vision and high-capacity arms, multiarm coordination, and dexterous "hands" must be developed. For inventory control, an automated storage and retrieval system suited to a hostile environment is required. A high-resolution vision module is needed for the quality control of complex products.

Further growth and increased complexity are required if the Seed Factory is to evolve from the starting unit into a sophisticated manufacturing unit. Laser, electron beam, and ion beam technologies in a clean vacuum environment could produce automated machinery capable of manufacturing highly sophisticated electronics, using raw materials supplied by the local environment.

Telepresence: The Next Best Thing to Being There

A *teleoperator* is a device that allows action or observation at a distant site by a human operator. Teleoperators represent an interim position between fully manned and autonomous robot operation. Teleoperators have motor functions, commanded by a human, with many possible capabilities, and have sensors to supply feedback information. The human controls and supervises operations through a mechanical or computer interface. As technology advances and new requirements dictate, more of the command and control functions will reside in the computer, as shown in the *Outpost* starship's virtual reality console in Figure 6-5, with the human performing a supervisory role. When artificial intelligence methods are developed and applied, the computer may perform "mental" functions of greater complexity, making the system more independent.

A teleoperator is in current use on the Space Shuttle. The shuttle has a 6-degree-of-freedom general purpose remote manipulator system (RMS) with a 50-foot reach. The RMS lifts heavy objects in and out of the payload bay and assists in orbital assembly and maintenance. An astronaut uses hand controllers to control the rate of movement of the RMS.

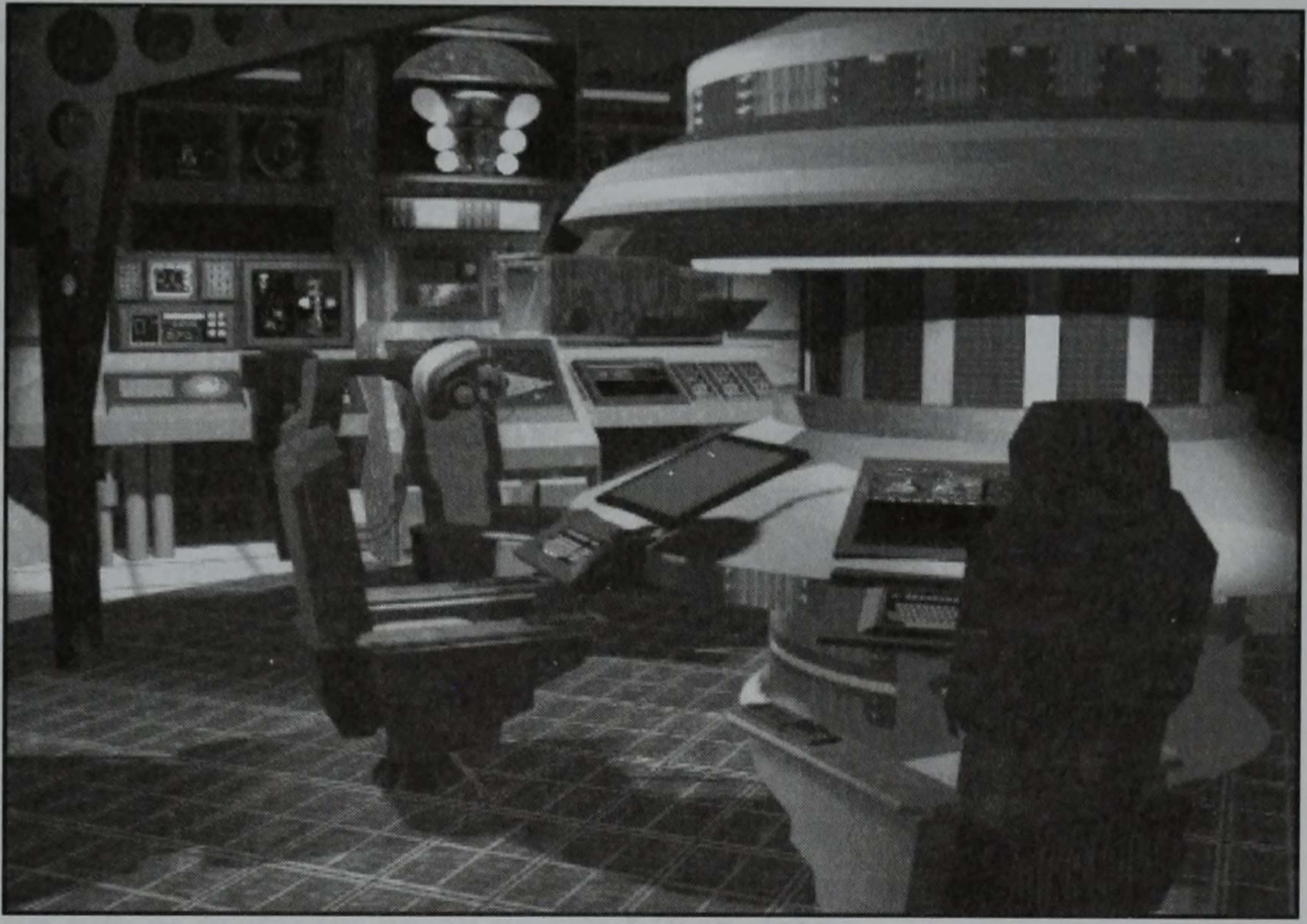


Figure 6-5

Teleoperation console on the *Outpost* starship

NASA, the Russian space agency, and the Planetary Society are currently testing a teleoperated mobile robot designed to explore Mars. The Mars Rover is a critical part of the Russian *Mars '96* mission, where it will serve as a wandering robot scientist to study the martian landscape. In a recent test, a team of scientists and engineers in California operated the rover through a satellite telephone link as it traversed the forbidding volcanic terrain of the Kamchatka Peninsula. Lacking only the 20-minute time lag in communications between Earth and Mars, this test was a successful simulation of what it would be like to operate the rover from another planet. Video images from the rover, supplied by a stereo camera developed in France, were transmitted to California for real-time interaction. The team watching the video display would analyze the terrain and decide where to drive the rover next. The stereo video was also run through a virtual reality program so that it could be displayed as a three-dimensional map on a Silicon Graphics workstation.

The uniqueness and utility of teleoperators lies not in their mode of locomotion, but rather in the telepresence they provide—the ability of the human to sense and affect a remote environment. About 40 percent of human sensory input is in the form of vision, so most work in physical perception relates to visual information processing through pattern recognition and scene analysis. However, a human teleoperator also needs a "feel" for the task the robot is performing. Marvin Minsky of the Massachusetts Institute of Technology (MIT) has noted that no existing system has a true sense of feel, and insists that "we must set high objectives for the senses of touch, texture, vibration, and all the other information that informs our own hands." In addition to communicating through sight and touch, an audio interface between human and computer is also feasible.

Robots for Hostile Environments

The Seed Factory in *Outpost* is equipped with a basic set of robots that will begin work as soon as they arrive on the new planet. Figure 6-6 shows a mining robot leaving the Seed Factory. The robots are a diligent bunch, ready to work for as long as their fuel cells and mechanical parts will hold out. Humans doing the same work could never be as effective in the hostile environment of a new planet, although they will be helping their mechanical pals through telepresence. The robots will wear down over time and need replacement, but part of the function of the Seed Factory is to produce more robots, and it will keep doing so as long as the raw materials keep arriving for it to process. Watching from the orbiting colonization ship, you have the option of determining which types

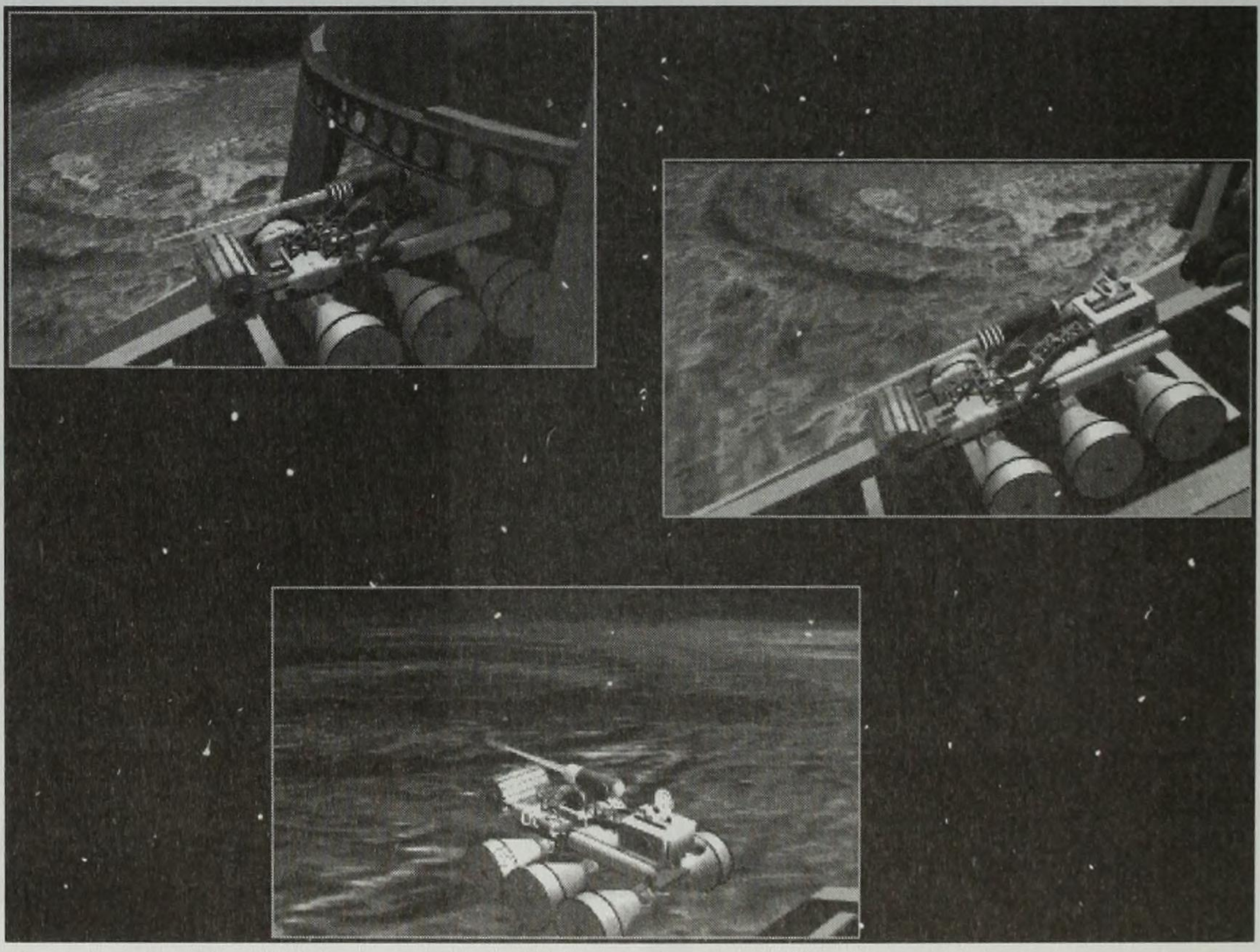


Figure 6-6

A miner robot goes to work.

of robots will be most useful to you and setting the Seed Factory to produce those robots.

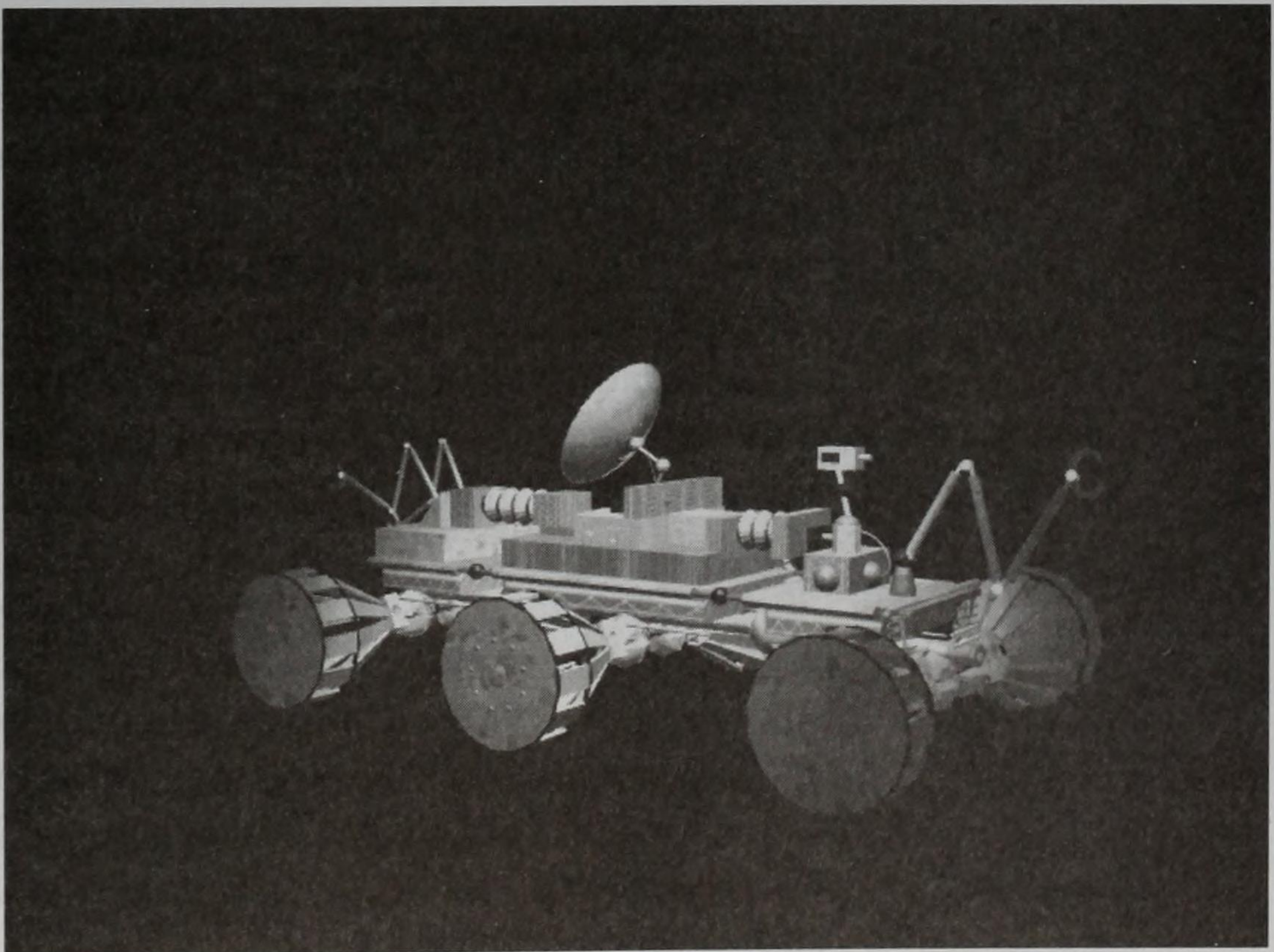
The explorer robot, shown in Figure 6-7, will designate mining locations, based on orbital information and direct site sampling, then mark them with a big red beacon so you'll know where they are. These are the red dots that appear on the Site Map. Figure 6-8 is a sample Site Map. The mining robot will dig a self-contained mining facility when you place it on one of the red mining beacons. It may take the miner a while to work down through several levels of rough terrain, but it'll eventually finish the job and report back for a new job assignment. The digging robot will tunnel below the surface, preparing the underground levels for human habitation. The bulldozer robot works both on the surface and underground, preparing a smooth and level surface where you can safely build your structures. The semiautomated transport vehicle, supervised by humans, will carry the mined ores to the small smelter on the Seed Factory for processing into building materials.

Habitat Construction

As the first robots leave the Seed Factory, production becomes centered on building a command and control facility that will become the core of your new colony. This facility also has a self-contained

Figure 6-7

Explorer robot



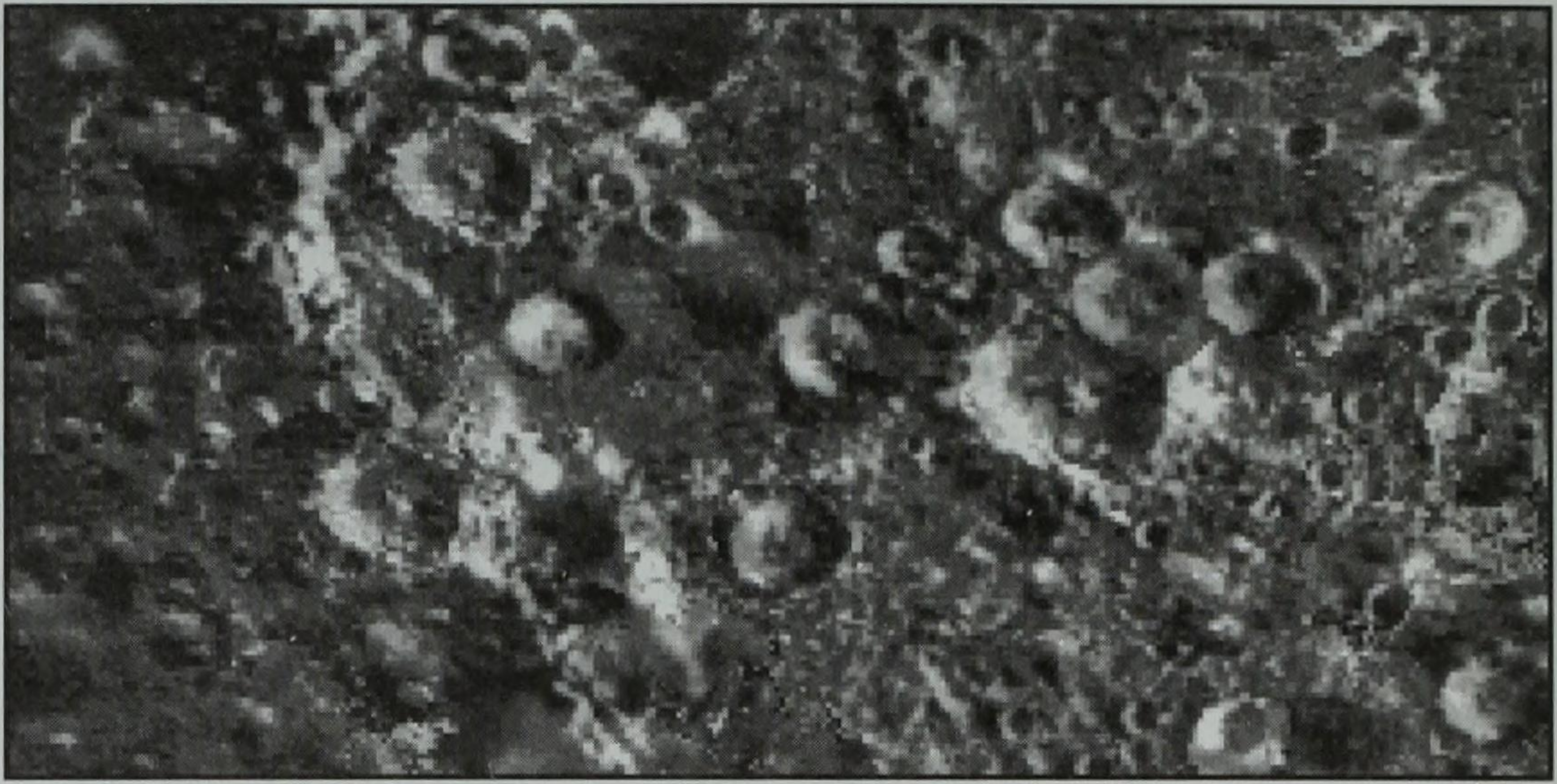


Figure 6-8

Landing Site Map generated from orbit

environment, allowing your first group of humans to land on the planet and find a welcoming structure waiting for them. It's a fine thing to have a warm home waiting on a planetary surface when you've just spent 60 years or so in deep space. I'm sure you know the feeling.

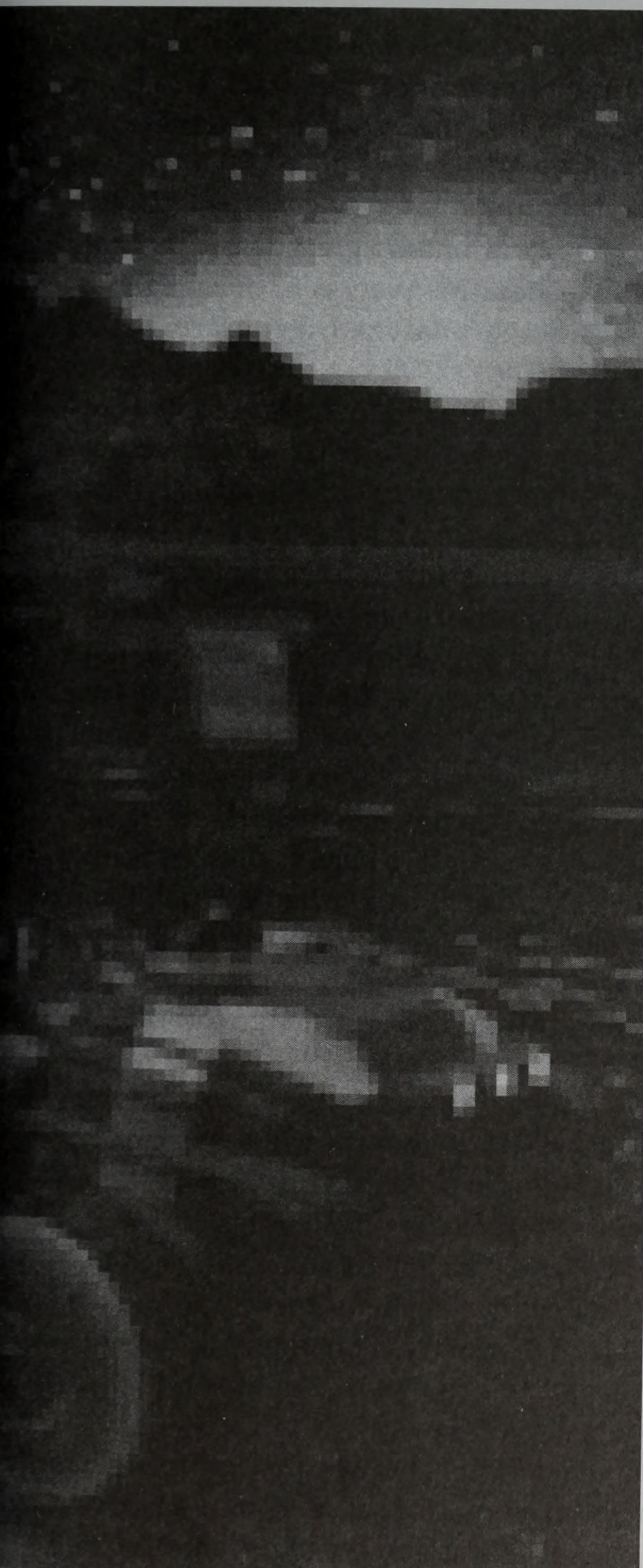
Power Generation

It's also nice to know that the light will come on when you hit the switch. The miracle of electricity brings this awesome power under your control. The Seed Factory uses a lot of power on its own, but it also supplies a limited amount of power to keep the early colony structures operating. A gift from the sky, the power supply is beamed down by microwave from the colonization ship. You'll need other power sources soon enough, but the Seed Factory will get you started.

In this chapter, I'm sure you've learned far more about Seed Factories, automated material processing, telepresence, and self-replicating von Neumann machines than you ever wanted to know. In fact, with all this technical detail on the subject, you could probably go out in your backyard and build a Seed Factory of your own right now.

But wait! There's more! In the next chapter, you'll learn about mining and the distribution of natural resources on other worlds. You might even find out how the mined ore is processed through the smelters, transported, and used by your colony. And to get all that, all you have to do is turn the page and read the next chapter. What a deal. You'll have a Ph.D. in something by the time you're through with this book.

Figure 7-1 Smelter receiving delivery



7

Mining and Resources

My suspicion is that the universe is not only queerer than we suppose, but queerer than we can suppose… I suspect that there are more things in heaven and earth than are dreamed of, in any philosophy. That is the reason why I have no philosophy myself, and must be my excuse for dreaming.

J.B.S. Haldane, *Possible Worlds* (1927)

The planetary systems in *Outpost* are based on the best data available regarding planetary formation around other stars. This is not a topic that scientists know a lot about, but certain inferences can be made on the basis of our own Solar System and the types of planets that have formed here. In the last few years, the *Voyager* probes, and many others, have contributed a great deal to the store of information we now have about the planets in our neighborhood. These data are still being analyzed, generating new discoveries every year.

In *Outpost*, the mining of local resources is necessary for the construction and survival of your colony. The distribution of resources is based on a number of geological principles, as well as on data about other planets gathered by space probes. However, *Outpost* is slanted more toward entertainment than toward being a textbook on geology. The simulation deals with resources in a simplified fashion to enhance the playability of the game, grouping resources into categories that are easy to understand. Where the presence of a particular resource on a particular type of planet is questionable, it has been added in small quantities so that the minimal limits of the simulation could be maintained.

This chapter is your guide to mining: where to find resources, how to reach them, and what to do with them when you find them. The resource distribution among the mines on different planets is described here in detail, and may be more than you want to know; if so, avert your eyes if you consider this knowledge forbidden.

Planetary Composition

Terrestrial planets tend to form at the same time as their primary star, which means that they all form from the same raw stock of materials. The variety of an individual planet's composition comes out of a process known as *chemical fractionation*, a selection process during the formation of a planet that rejects some raw materials and keeps others. Every planet has a core of rocky and metallic compounds. On top of that, the primary components of the Earth are the elements oxygen, silicon, aluminum, and iron, which are all present in small amounts in the Sun.

Fractionation had a different result in the proportions of elements on Mars. As a more detailed example, the soil of Mars is 42 percent oxygen, 21 percent silicon, 13 percent iron, 3 percent aluminum, 5 percent magnesium, 4 percent calcium, 3 percent sulfur, with trace amounts of hydrogen, sodium, chlorine, titanium, and potassium. This composition corresponds to terrestrial or lunar basalt lava, but the martian soil contains less aluminum than terrestrial basalt and less titanium than lunar basalt.

In terms of overall cosmic distribution, hydrogen is the most abundant element, followed by helium, carbon, nitrogen, oxygen, neon, magnesium, silicon, sulfur, and iron. Terrestrial planets tend to miss out on light gases, which favor the gas giant planets such as Jupiter. With all that hydrogen and oxygen around, we can expect that water will be one of the most common chemicals we come across on other planets.

Resource Types

The resources in *Outpost* are combined into convenient groupings so that you don't have to know a lot about chemistry just to keep your colony operating. In practical use, you may be aware that a particular facility requires two or three of the following resources, but you don't have to understand how that facility makes use of those resources. You will also see that the mined, unprocessed form of a resource is treated separately from its refined state after it has passed through a smelter, such as the one shown in Figure 7-1.

With regard to the terminology, mining activity generates *ore*. When the ore is processed, the components are then listed in their individual categories, such as *Life Support A*.

Mined and Processed Resources

The four categories of resources that must be mined are the Life Support Group, which includes such basic necessities as water and oxygen; the Metal Group, which comes in handy when you want to build a colony; the Fusion Group, which keeps your tokamak reactor and a variety of other things operating; and the Mineral and Precious Metal Group, which includes gold locked in quartz, both of which can be used as raw materials by your colony after they've been processed through the smelter.

Life Support Group
  Life Support A (LSA)
  Life Support B (LSB)
  Life Support C (LSC)
Metals Group
  Metal Ores A (MOA)
  Metal Ores B (MOB)
  Metal Ores C (MOC)
  Metal Ores D (MOD)

Processed Metals A (PMA)
Processed Metals B (PMB)
Processed Metals C (PMC)
Processed Metals D (PMD)

Fusion Group

Fusion Elements A (FEA)
Fusion Elements B (FEB)
Fusion Elements C (FEC)

Minerals and Precious Metals Group

Minerals A (MA)
Minerals B (MB)
Minerals C (MC)
Precious Metals A (PRMA)
Precious Metals B (PRMB)

Other Resources

Besides the materials that must be mined, there are other resources generated as the result of your factory production, by your colonists in their spare time, or as by-products of the functioning colony.

- **Food** Created by your agricultural domes, enhanced through research
- **Luxury** Created by your light manufacturing facility and distributed through commerce
- **Population** Created by your colonists when they aren't working
- **Power** Created by the Seed Factory and other power facilities
- **Breathable Atmosphere (BA)** Created by the CHAP (closed habitat atmospheric production) facility for your buildings
- **Colony By-Products**
  - Sewage (SWG): Created by your organic colonists. Recyclable
  - Waste Material (WAM): Created as a result of factory operations. Recyclable
    - Multipurpose Goo (MPG): Recycled wonder material from the SPEW (sewage processing and environmental waste) facility

Distribution of Resources

The distribution of resources among the mines is based on the composition and environment of a particular planet type, reflected in the value called Planetary Hostility. If you have chosen to colonize a planet with a high Hostility rating, your reward is a greater abundance of resources that can be mined. A "happy" planet with a low Hostility rating will have fewer resources and require a greater amount of mining activity to keep a colony functioning. Of course, the environment takes its toll, so it's harder for your colony to survive as the Hostility rating goes up. The exception to this general rule of mining is a small planetoid or asteroid that is too small or frozen to support a large number of mines and resources.

On average, any mine will have a mixture of ores, with Life Support, Metals, and Minerals being most common, followed by the Fusion Group elements. As a general guideline, Metal Ores A and Minerals A are more common on the planet than B-grade ores, which are more common than C-grade ores, etcetera. Precious Metals appear as processed components of B- and C-grade minerals, but only in small amounts. Once processing has been completed in a smelter, you will know the exact breakdown of resource quantities available for your use.

Table 7-1 shows the total number of mines on planets of a particular Hostility level. For each Hostility level, the base value (unmodified by other factors) of resources per turn is multiplied by the total number of mines to give an approximation of the total yield possible per turn.

The results of individual mine production calculations will vary, as a number of modifiers are applied to the mining formula. Production is affected by the local terrain, the depth of the mine, local resource distribution, and some random variation to reflect mechanical and human difficulties involved in the mining process.

Robot Explorers and Miners

As background for our discussion of robot explorers and miners, let's put them in context by looking at the different ways you can gather information about resources on your planet.

Starship From orbit, your starship's instruments can identify the Hostility level of your new planet, surface mineral deposits indicating reasonable mine locations, and basic planetary data. By analyzing this data, the artificial intelligence (AI) personality generates landing Site Maps with the red diamonds that mark potential mine locations.

Geological surface penetrator From orbit, you can launch a surface penetrator, such as the one shown in Figure 7-2, at the planet. The AI personality will analyze these data to give you the maximum digging depth for your miners and diggers, an estimated

Table 7-1 Total Mines per Hostility Level

Hostility Rating	Total Mines	Resources per Turn	Total Resources per Turn
1	105	13	1365
2	130	9	1170
3	15	9	135
4	15	14	210
5	15	16	240
6	35	21	735
7	180	20	3600
8	125	23	2875

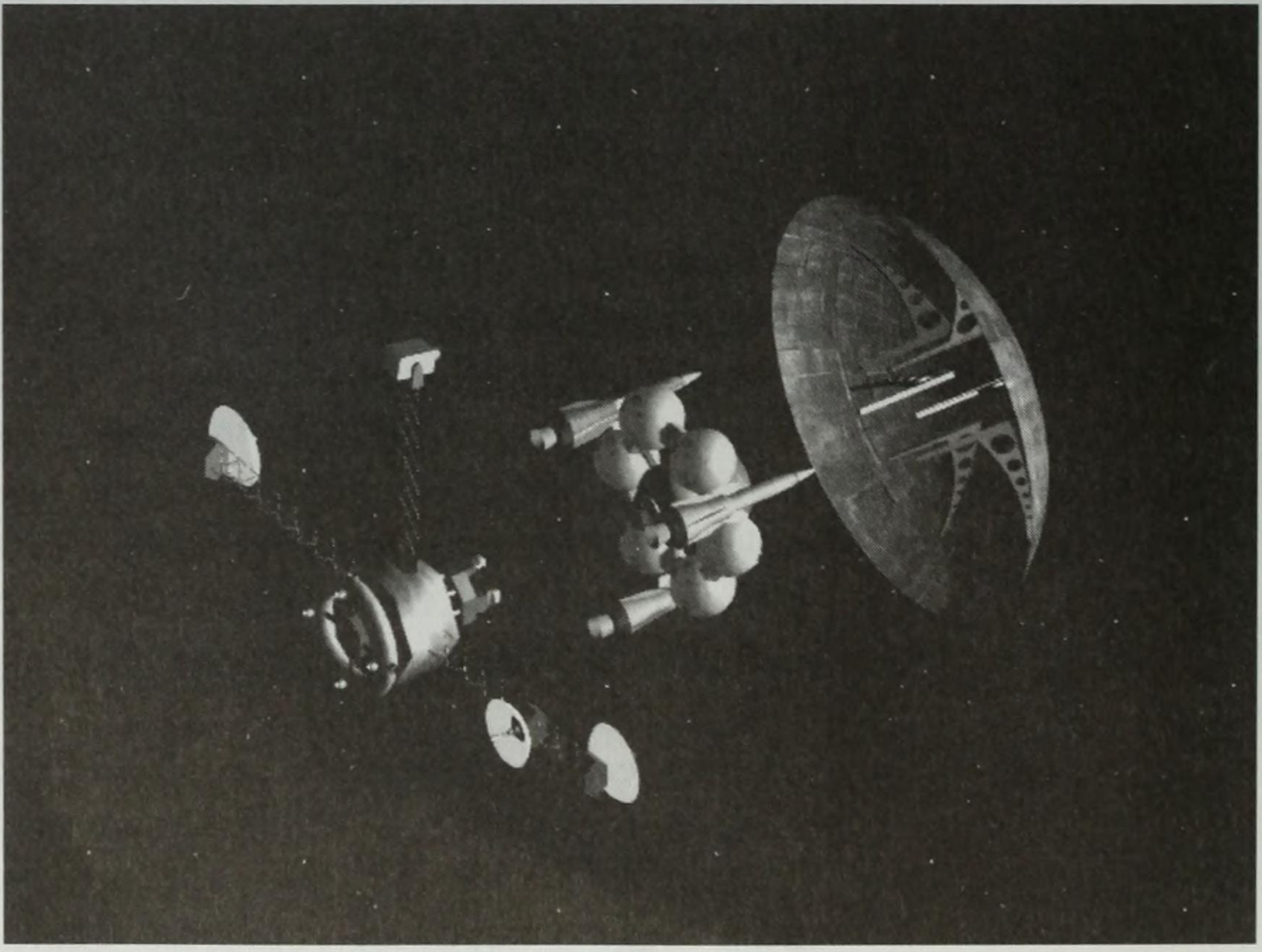
total number of mining locations, and a general indication of the planet's primary resources.

Robot explorer The explorer robots can investigate potential mining sites identified from the starship and indicated on the landing site map. This investigation will reveal the exact concentrations of resources in the potential mining location. The explorer can also come across new mining locations, which it marks with a red beacon.

The first explorers from the Seed Factory will automatically check out the potential mining sites located from orbit. Later explorers

Figure 7-2

Surface penetrator probe



can be set to seek out new mines. As robot production increases, it's a good idea to keep several explorers running around looking for mines, just to make sure you've found all of them.

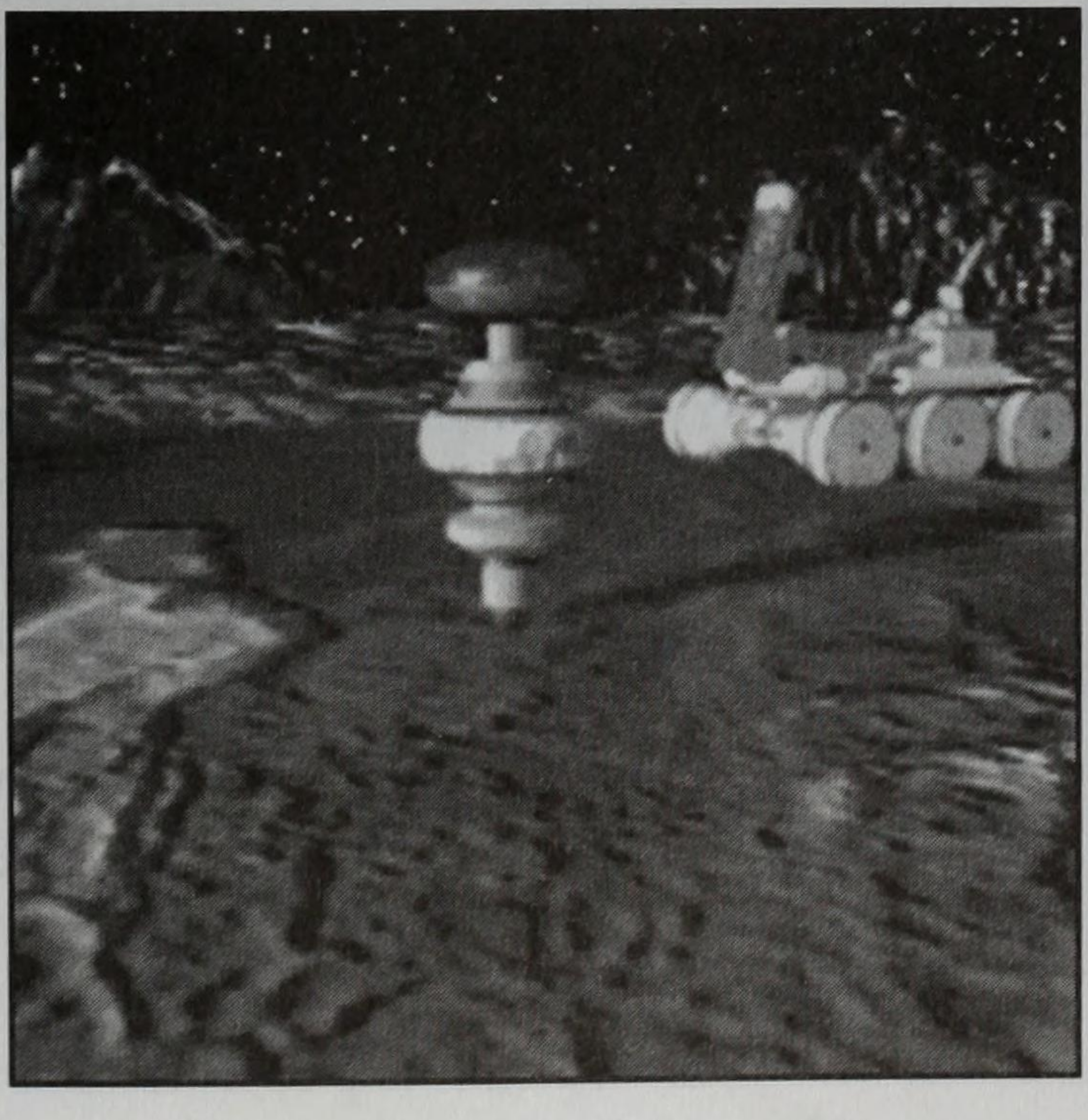
The mining robots will dig only where a red mining beacon has been planted by an explorer robot. Figure 7-3 shows an active mining beacon. The mining beacon sends out a navigational radio pulse so that the miners can find it. Once it has found a mining beacon, a miner will plunge into the earth with single-minded devotion to its task, digging straight down and building a mine shaft as it goes. As it completes each level of the shaft, it retraces its route to the surface, establishing an elevator and automatic digging system. As the mine starts pumping high-grade ore up to the surface storage facility at the top of the mine shaft, the miner robot will wait for new orders before it tries to dig the shaft any deeper into the planet. Once the maximum digging depth has been reached, the miner will refuse to dig any further. The ore in storage at the top of the mine shaft can be picked up by truck or monorail for shipment to the smelter.

Mining and Ore Processing

Any mine will "play out" after it has been worked long enough. As long as a mine is active, and not temporarily shut down due to a storage capacity limit or repairs, it will generate ore for a period of 100 to 400 turns, depending on the digging depth of that planet. So, if level 3 is the maximum depth for that planet, the mine will

Figure 7-3

Mining beacon



operate for 300 turns; if level 4 is the maximum, it will operate for 400 turns.

On a very hostile planet, where the digging depth is only one level, it would be wise to build quick and start recycling through the SPEW facility as soon as possible. This technique will generate multipurpose goo to make up for resources that can't be mined.

As soon as ore has been delivered to the smelter/ore processing facility, the production of useful resources begins. The ore is sorted, then processed into resources by using specific conversion values. The quantity of Metal Ores A (MOA) is detected by the sorter, then converted to Processed Metals A (PMA) at a ratio of 2:1, so 100 units of MOA will produce 50 units of PMA. This conversion factor is true for all metals.

Minerals are processed at a 1:1 ratio, so that 100 units of Minerals A (MA) will be processed into 100 units of purified MA that can be used by the colony. A special component of Minerals B and C is that they can contain Precious Metals, which are extracted during the smelting process.

Fusion Elements are also processed at a 1:1 ratio. By passing through the ore processing facility, the impurities in the Fusion Elements are removed to produce reactor-grade nuclear material. A tokamak reactor requires substantial quantities of all three elements to produce power.

Industry on the Move: Transporting Your Ore and Resources

In *Outpost*, you are provided with two methods of transporting ore and resources—by monorail or by truck. Storage capacity of an active mine is limited to 500 units of ore. When the maximum storage capacity is reached, the mine shuts down production until the stored ore is removed. To avoid this problem, a truck can pick up the ore stored at the mine and move it to a smelter for processing. Each truck can carry 100 units of ore. The same truck can pick up 100 units of processed resources from the smelter and deliver it to your colony's storage tanks. Until the resources have been loaded into storage tanks, they remain unavailable for use by the colony. Trucks can use bulldozed dirt roads, but they will move much faster on paved roads.

A monorail can carry 500 units of ore to the smelter, so you may find it useful to build a monorail line between several active mines and a centralized smelter. The monorail is much faster than a truck, but it also takes more time and money to build a monorail line than it would take to build a paved road for trucks over the same route. This monorail can make regular runs, perhaps making its pickups when each of five mines has 100 units of ore sitting in storage, then taking the load to the smelter for processing. In the same way, another monorail line could connect the smelter to your colony's storage tanks, making the processed resources available for use at a faster rate. A monorail is shown leaving the station in Figure 7-4.

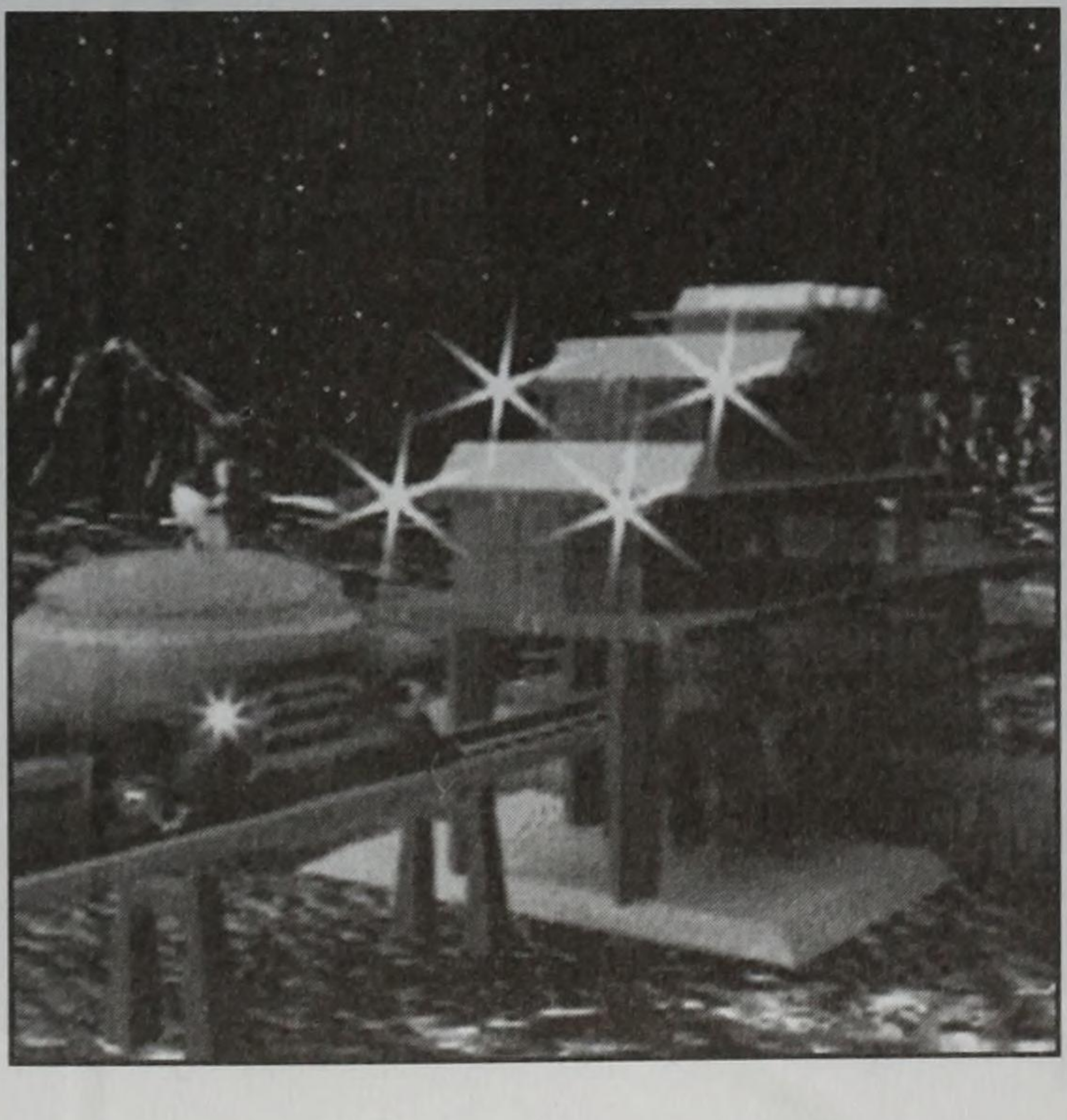
A more detailed discussion of the advantages and disadvantages of trucking versus monorails can be found in Chapter 12.

Now that you've learned the cosmic secrets of planetary composition, resource distribution, mining, ore processing, storage, and the transportation of resources, you should have a better understanding of the resource lifelines to your colony. You can relate this to conditions on Earth, where a remote mountain community is dependent on trucking to maintain its flow of supplies. If that flow was cut off on a permanent basis, the individuals in the community would have to drive long distances to obtain those same supplies, and the trouble it caused them might well force them to move away. In *Outpost*, the individual colonists are unable to get their own supplies, but they can decide to defect to the rebel colony if supplies are cut off for too long and morale drops too low. Your colonists have the added stress of their need for life support materials. By understanding the importance of your supply lines, such defections are less likely to occur among your population.

The next chapter will illuminate you on the subject of power.

Figure 7-4

Monorail



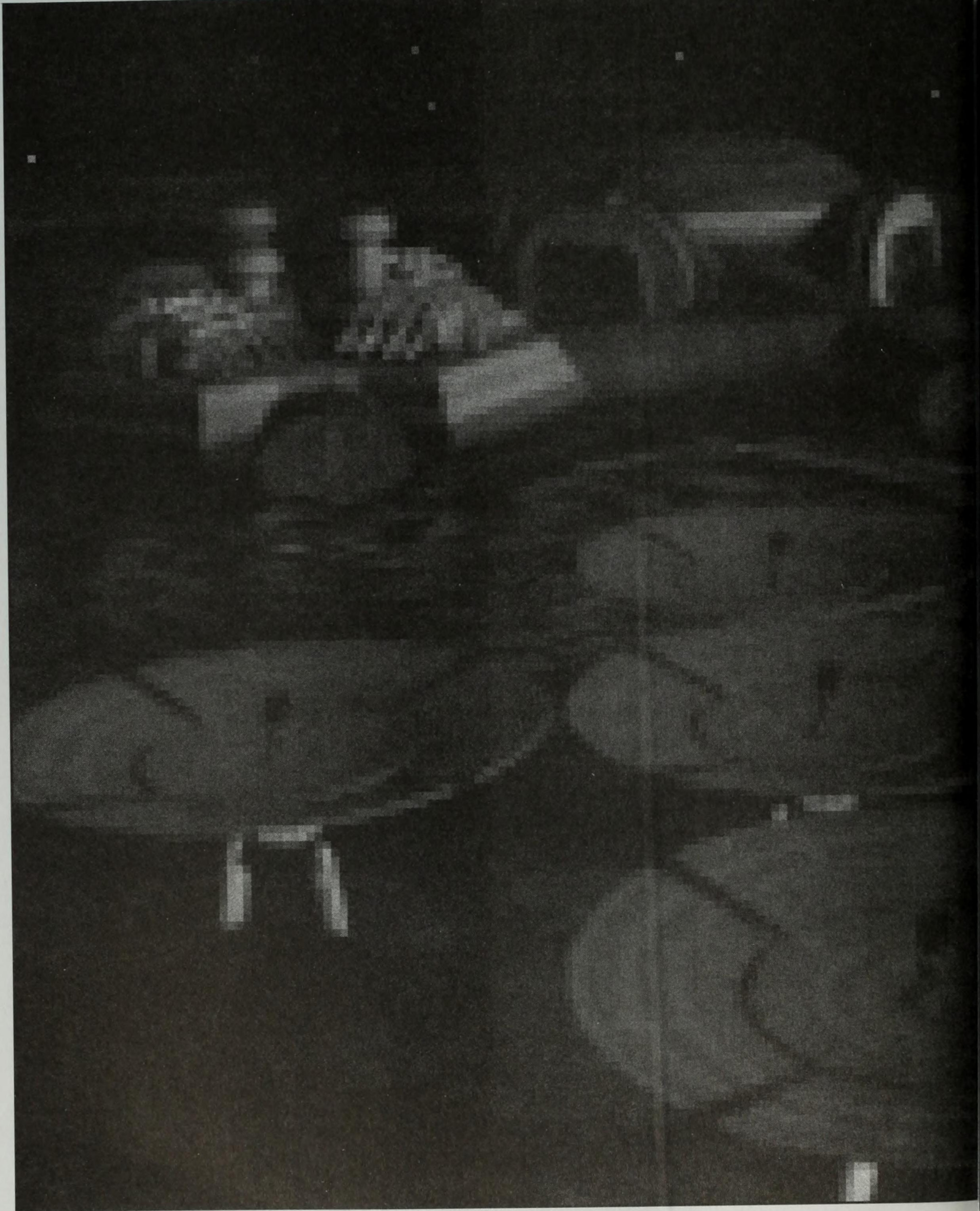
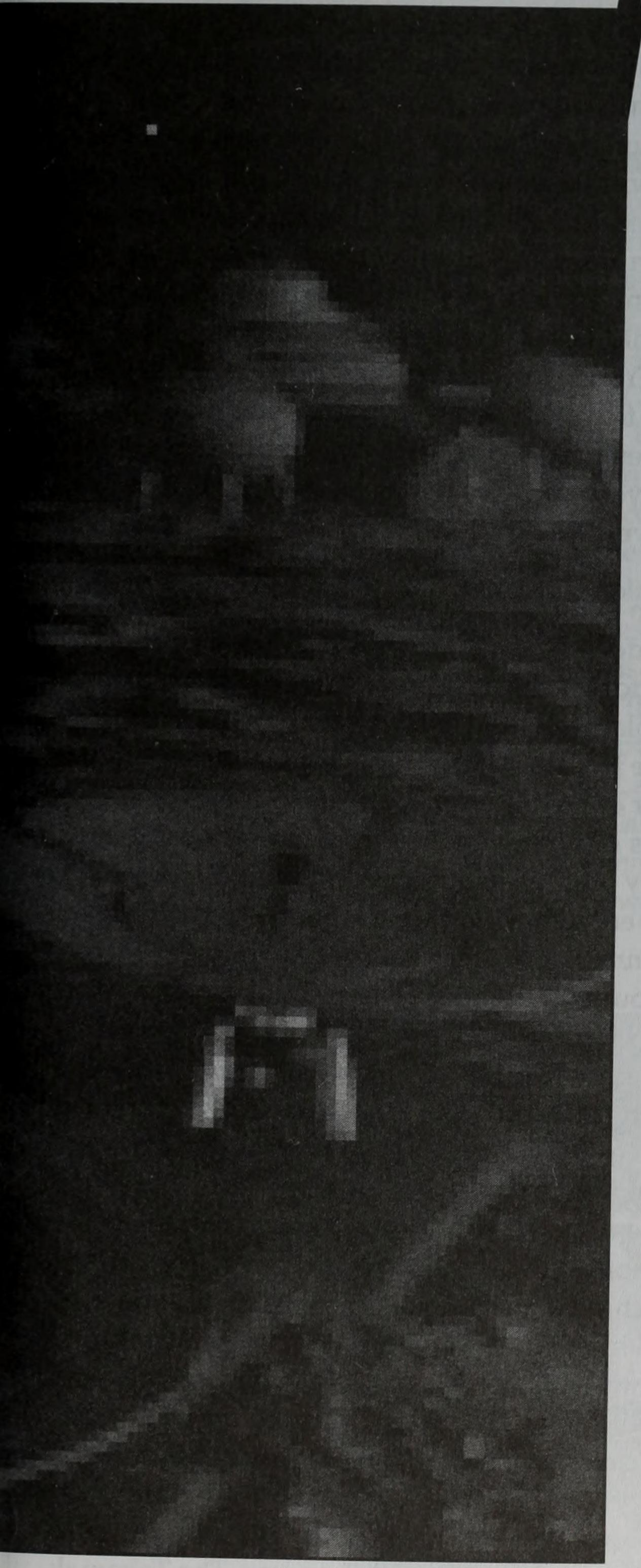


Figure 8-1 Powersats beam power to these receiver arrays.



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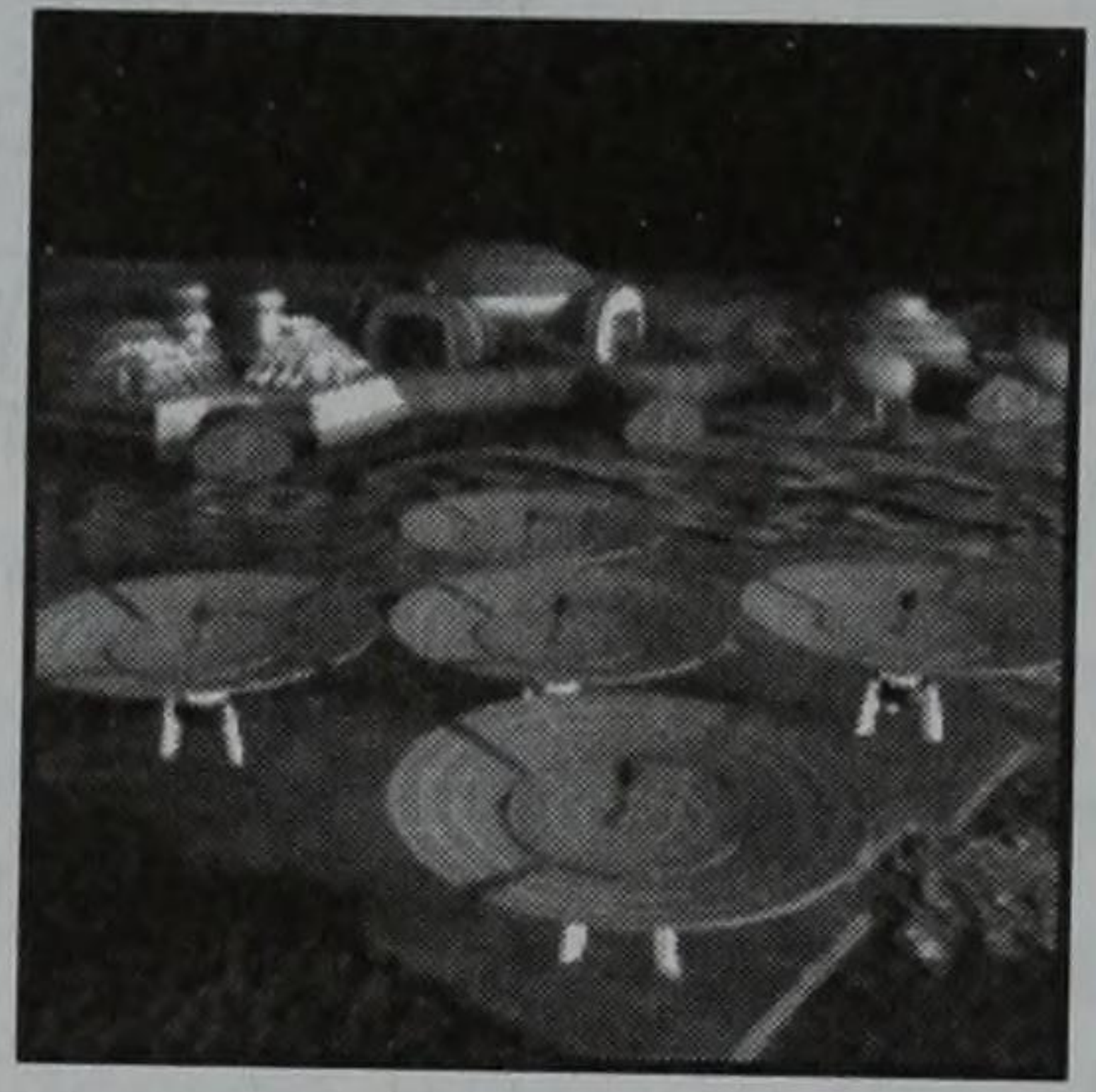


Power to the People

A prince who builds his power on the people,
who can command and is a man of courage,
who does not despair in adversity, who does
not fail to take precautions, and who wins
general allegiance by his personal qualities
and the institutions he establishes, will never
be let down by the people; and he will be found
to have established his power securely.

Niccolo Machiavelli, *The Prince*

Power. You know you want it. You know you need it. You want to know how to get it. The kind of power Machiavelli was writing about is useful in managing your colony, but it won't help you generate the energy you need to survive. If you don't generate energy, your colony will be a lifeless and dark hole, populated only be robots until their fuel cells die out. The expansion of your colony will depend on three things: the morale of your population, the availability and mining of your local resources, and the energy required to build new structures while maintaining your existing power needs. You can centralize your power facilities and use economies of scale to distribute energy across your new world, or localize your facilities to develop the safety of redundancy. Limited energy can limit your growth, while excess energy can be a tool for economic power.

Methods of Power Generation

Outpost allows you to generate power through several different means. You may wonder, however, why such obvious systems as wind and hydroelectric generators were left out of the list.

Assuming that the planets of the solar system are typical, with Earth being a possible but least likely type of planet to form, we are left with a number of hostile environments to colonize. Ranging from the extremes of no atmosphere to dense atmosphere, a wind generator on any other planet than Earth would either have no wind to move it, or enough wind to tear it apart. As an example, during the windy summer season on Mars, the winds can exceed 200 miles per hour. You might think this is enough to tear a wind generator apart, but in fact the low-density air of Mars has far less force than the winds on Earth. A wind-driven system would be useless. Hydroelectric generators would face a similar problem on other worlds, where they would have to function in oceans of supercold or superhot liquids to have any value.

What does that leave us with? A couple of big power generating systems and a couple of small ones, all of which are based on current or near-future technologies. Energy will need to be generated according to local environmental demands and the availability of resources on your new world. The Seed Factory, shown in Figure 8-2, supplies only enough power to start your colony. The solar power satellite is a clean and efficient power system, but can't be used to provide energy for planets that are too far away from their local stars. The geothermal system requires the fortunate event of coming across an underground geothermal source. The Tokamak

Fusion Reactor is reliable and efficient, but complicated to build. Fuel cells are fine for robots and other small energy needs, but cannot meet the demands of large-scale colony operations.

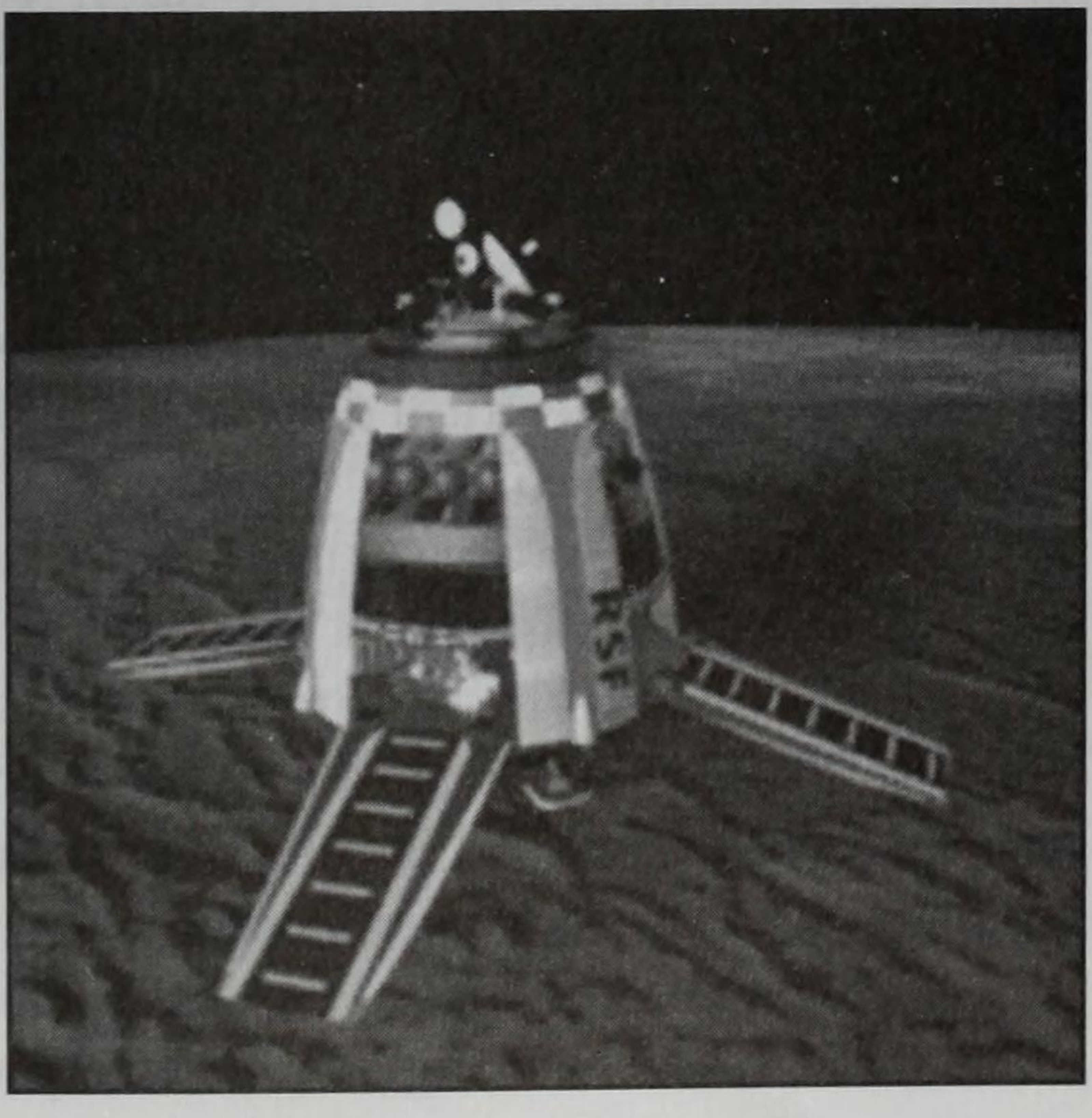
Solar Power Satellite

In the late 1800s, Konstantin Tsiolkovsky, the visionary Russian space pioneer, described his 14-step plan to conquer space. His plan allowed for solar power in space for energy. Refining his plan in 1912, Tsiolkovsky proposed using solar energy beamed down to Earth from orbital satellites. Thinking along similar lines, Nikola Tesla lectured on his idea of wireless power transmission near the turn of the century. However, it was not until 1968 that the two ideas united in the mind of Peter Glaser, who proposed that large arrays of solar cells could be positioned in geosynchronous Earth orbit. From there, the solar power satellite, as shown in Figure 8-3, could convert the solar energy collected through the photovoltaic cells into microwaves. These microwaves could be beamed down to receiving antennas on the ground for conversion back into electricity, then fed into the transcontinental power grid.

To prove the concept, a power beaming test was set up in 1975 by the Jet Propulsion Laboratory and Raytheon. At the Goldstone tracking station in California, microwave energy was transmitted from a tracking antenna to a receiver array on a hill over a mile away. The 400-kilowatt beam was converted to direct current

Figure 8-2

The Seed Factory provides minimal power.



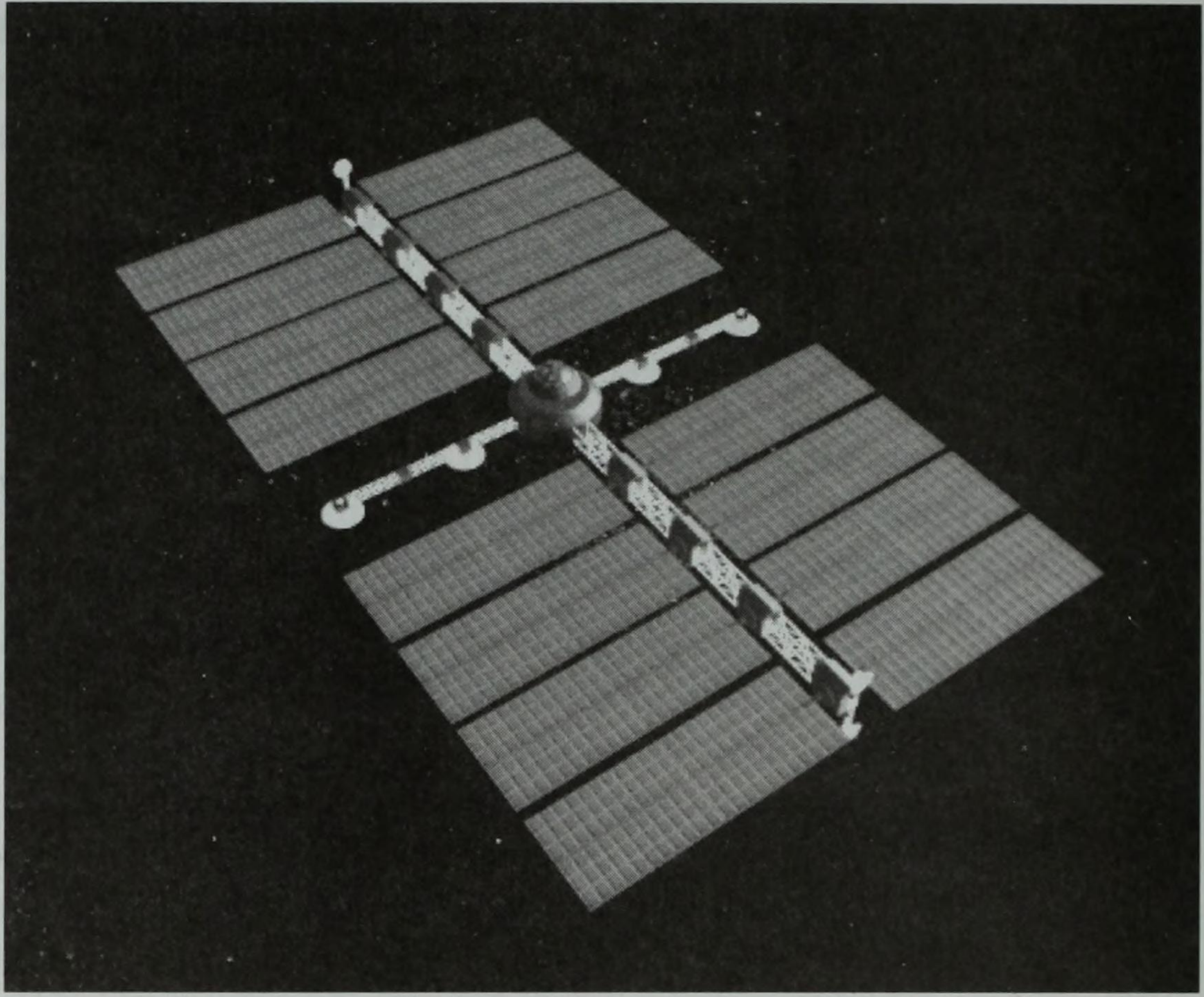


Figure 8-3

Solar power satellite

electricity at the receiving panels, then used to light up a bank of 17 lights. The receiver panels were not designed to intercept the entire beam area, catching only about 10 percent of the microwave energy. However, with an efficiency of 82.5 percent, the test was successful enough to initiate $22 millions' worth of research by NASA and the Department of Energy. This resulted in a fleshed-out "reference system" that could be used for further study.

The reference system used 60 solar power satellites. Each satellite would weigh about 50,000 tons and cover an area about the size of Manhattan. Five gigawatts of power would be generated by each satellite, collectively generating enough power to replace all other means of electrical generation in the United States. Such a system would require 30 years to build and place in orbit. Because of the immensity of such a project and its $1 trillion price tag, research in this area died off for several years. However, recent studies have renewed interest in the subject of solar power satellites. Also, as this research has slowed in the United States, Japan has leaped ahead in running test projects to result in a 10-megawatt satellite power beaming system by the year 2000.

The solar power satellites in *Outpost* do not operate on a massive scale. We're also assuming advances in photovoltaic technology to increase their efficiency and reliability. As a result, each satellite generates up to 2000 units of power per turn, beaming power down to two solar receiver arrays. If only one receiver array is used, half of the tight-focus microwave beam will be missed, resulting in only 1000 units of power per turn under optimum conditions. Of course, it's possible to bring several power satellite/receiver combinations with you to your new colony, allowing you to establish a redundant and reliable solar power system with a tremendous amount of energy. The only problem with this method is that your new planet may be too far away from its primary star to make full use of a solar power system. If the solar energy is too feeble, you'll need to find another primary source of power generation for your colony.

Geothermal Energy

Although the surface of the Earth seems quite stable and comfortable to live on, it was once a molten mass of gas and liquid. Twenty miles below our feet, it's as hot as it ever was. Surface fractures, some of which are only 5 miles below us, collect the steam from that residual heat. Geothermal wells, which are drilled in much the same fashion as oil wells, seek out those pockets of steam, which are known as *fumaroles*. Whereas geysers spout boiling water along with their steam, fumaroles consist of the pure steam preferred by the turbines that drive electrical generators. At the present time, there are a small number of geothermal generating plants that take advantage of this cheap and clean energy source in Italy, New Zealand, Japan, Iceland, Russia, and California. Once again, we can assume that this leftover energy from the formation of our planet is not unique and, in fact, might be easier to tap on other planets.

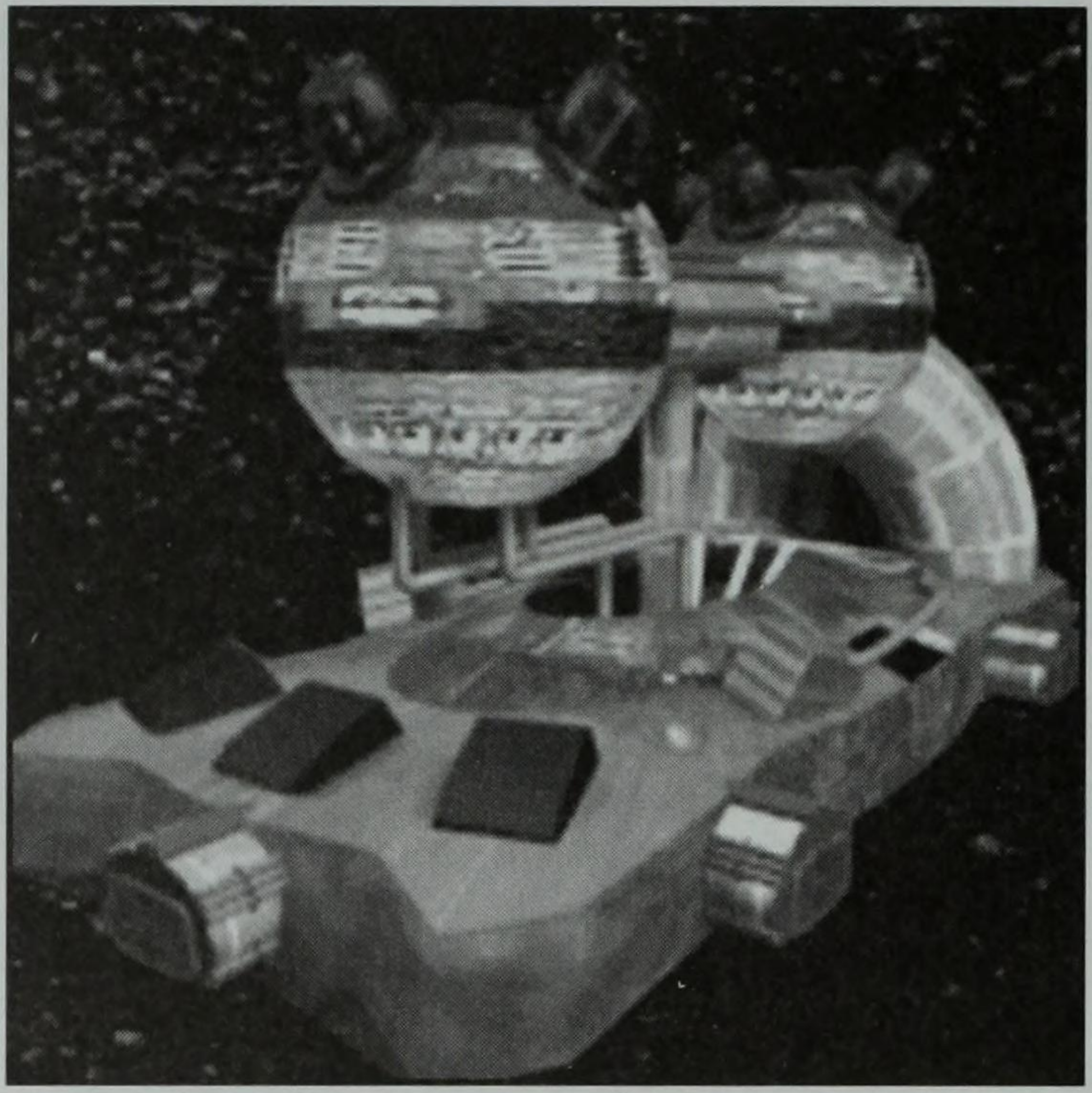
In *Outpost*, you have the ability to tap underground geothermal sources. The drawback is that you can't depend on locating such an energy source, because it requires a certain amount of luck even if the local area shows evidence of being geothermally active. Once you've found a fumarole and tapped it with your Geothermal facility, as shown in Figure 8-4, it will be a reliable source of power, although not as powerful as a solar powersat or tokamak reactor.

Fusion

In the 1950s, Lyman Spitzer proposed confining a *plasma*, a hot gas composed of charged particles, within a magnetic field. This "magnetic bottle" would contain a plasma of deuterium and tritium

Figure 8-4

Underground geothermal power plant



that might be heated up to 100 million degrees centigrade. Because the nuclei of deuterium and tritium atoms have positive charges and repel each other, they must be moved fast enough through heating to overcome their repulsion and fuse together. As you can see, this process has many similarities with the problems of single people and dating in our fast-paced society.

The energy produced as a result of this hot magnetic containment would imitate the reactions that power the sun. After all, a star is just a long thermonuclear explosion held together and fed by gravity. A star's size is a continual negotiation between the crush of gravity seeking to collapse it and the heat blowing it apart.

The magnetic bottle seemed like a straightforward idea, but there were problems with the first fusion experiments. At Los Alamos, the Perhapsitron was built, presumably with more confidence in the process than was reflected in the name, but the magnetic bottle leaked and the plasma escaped. At Princeton, the Stellarator had the same problem with trying to confine the unstable plasma. However, a breakthrough came from the Soviet Union in 1968 when Lev Artsimovich, the director of Moscow's leading fusion research center, announced the results from their new tokamak device. The word *tokamak* is the Russian acronym for "toroidal magnetic chamber."

The tokamak resembles a big donut. The magnetic forces inside this toroidal shape keep the superheated plasma from dissipating as it had in earlier magnetic confinement designs. So, the tokamak took over as the preferred fusion device, and many refinements were made to the initial design by laboratories in the United States. By 1978, the Princeton Large Torus had raised the internal temperatures to 60 million degrees centigrade, demonstrating that the confined plasma could still be stable at that high temperature. The sun manages to produce fusion at only 15 million degrees centigrade, but we need to produce higher temperatures to make up for the lack of pressure that aids fusion inside a star. Despite all the progress in this area, the condition of *breakeven*, where more energy is produced than it takes to operate the experiment, has not yet been reached.

As a basis for comparison, the Shiva device constructed at the Lawrence Livermore Laboratory was designed to deliver more than 30 trillion watts of optical power in less than one-billionth of a second. Shiva uses a different method to reach its goal, laser confinement, which concentrates the power of multiple lasers to compress a tiny amount of tritium-deuterium plasma fuel. The engineering required to pass this heat energy through a turbine to generate electricity, as a nuclear fission reactor heats steam to power an electric generator, is a separate problem under study.

The tokamak reactor in *Outpost*, shown in Figure 8-5, is a steady-state refinement of the original pulsed-plasma tokamak. It generates 1000 units of power per turn and its relative efficiency is high, but it still can't compete with a solar powersat orbiting the fortunate planet that's close to its primary star. Over time, the tokamak will require maintenance to keep it operating at full capacity. Heavy internal components can be weakened by the long-term exposure to intense heat and radiation.

Fuel Cells

The *fuel cell* is a special kind of battery. Its operating principles were first discovered in 1839 by Sir William Grove, but the device was not considered useful and was treated as a laboratory curiosity for many years. In the 1960s, scientists rediscovered the fuel cell and used it to make electricity for spacecraft.

The fuel cell resembles a conventional battery in that it has a positive electrode, a negative electrode, and an electrolyte. However, it produces electricity by the electrochemical combination of oxygen and some fuel that contains hydrogen. This fuel can be hydrogen gas, methyl alcohol, petroleum, natural gas, or propane.

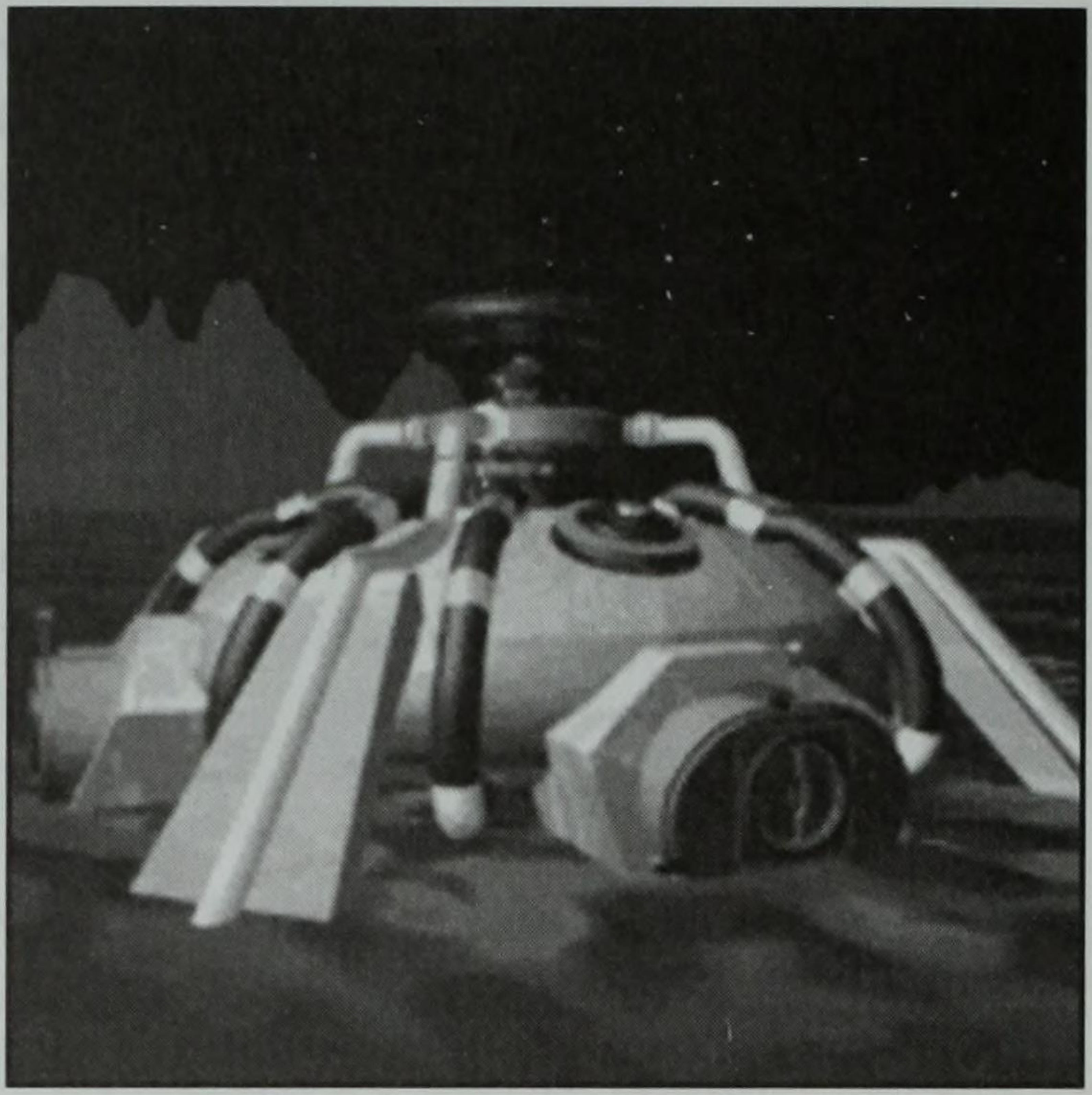


Figure 8-5

Advanced tokamak fusion reactor

Passing over the positive electrode, the fuel dissociates into hydrogen ions and electrons. The ions enter the electrolyte and move to the negative electrode. The electrons move through an external circuit to produce a current. At the negative electrode, the ions, electrons, and oxygen combine to form water.

Fuel cells are affected by their electrolyte, operating temperature, oxidant, and fuel. Numerous combinations of these are possible. Common electrolytes include phosphoric acid, potassium hydroxide, and sulfuric acid. The operating temperature can range from 120 degrees Fahrenheit to more than 1800 degrees Fahrenheit, depending on the fuel and electrolyte combination.

The good point about fuel cells is that they're as simple to use as a battery. They're appropriate for use on robots and other small energy users, where the cells will keep working until they die and have to be replaced with new cells. This means that a large fleet of robots will need a steady supply of new fuel cells, which must be manufactured by your colony.

Okay, so now you have a technical grounding in the good points and bad points about power generation in *Outpost*. Because the energy supply for your colony can be so restrictive to future growth, you now have the information you need to decide whether to spend the long construction time and mine the extensive resources required to build a tokamak reactor, or whether you should start an extensive search for underground geothermal energy. Solar power satellites could be the answer for your situation, but you need to bring them along in the colonization ship or do the research and mine the resources to build them on your colony. At least you know that the robots won't be drawing on your centralized power supplies.

When the energy and resource issues are resolved, you become the architect of your own future. You have a wide variety of structures you can build on your new world, all of which serve one or more useful functions. The interactions between the facilities you construct have a direct effect on the mathematical model that drives the simulation, so it's worth spending some time to understand the importance of each building type. These things, and more, are explained in Chapter 9.

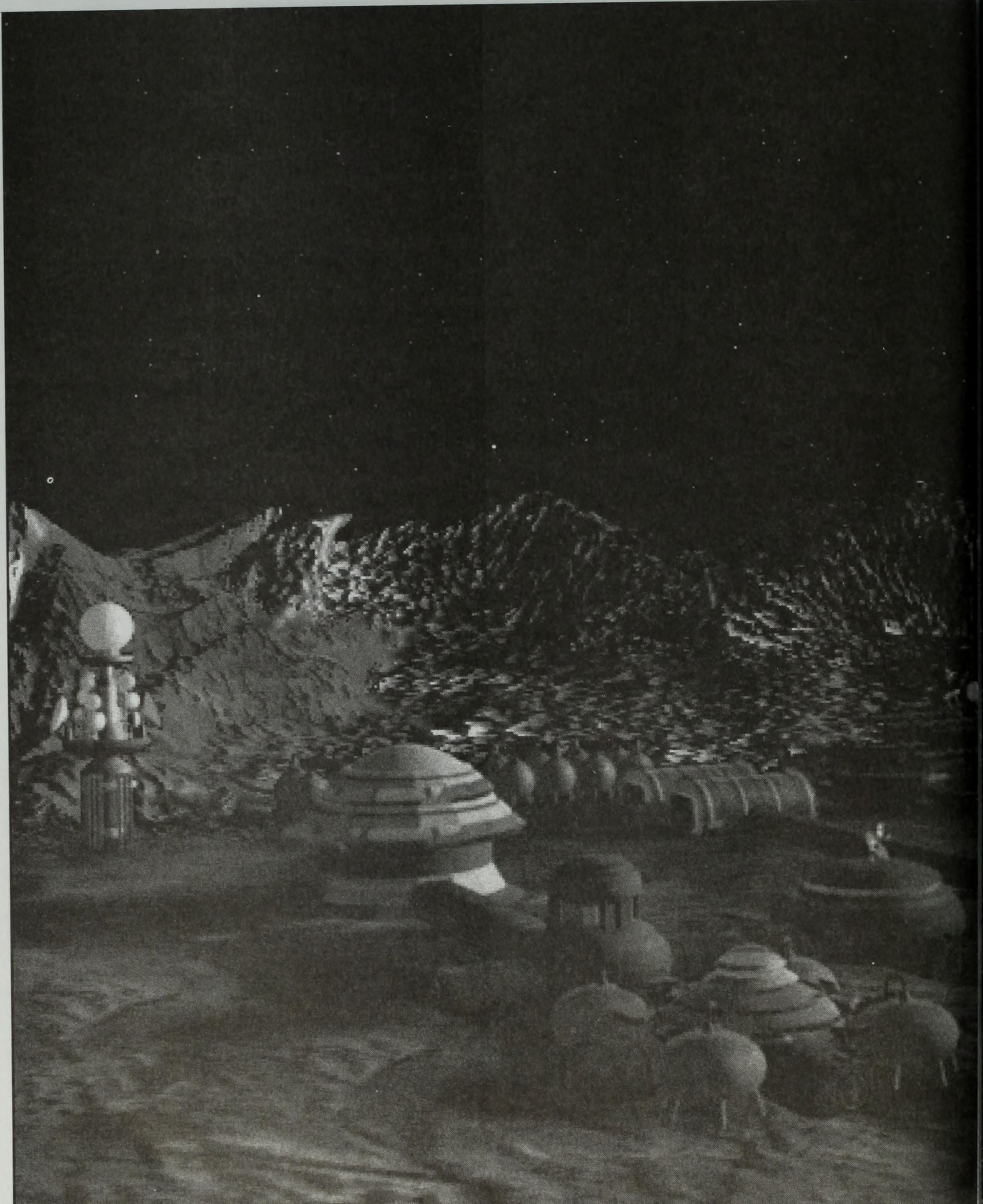
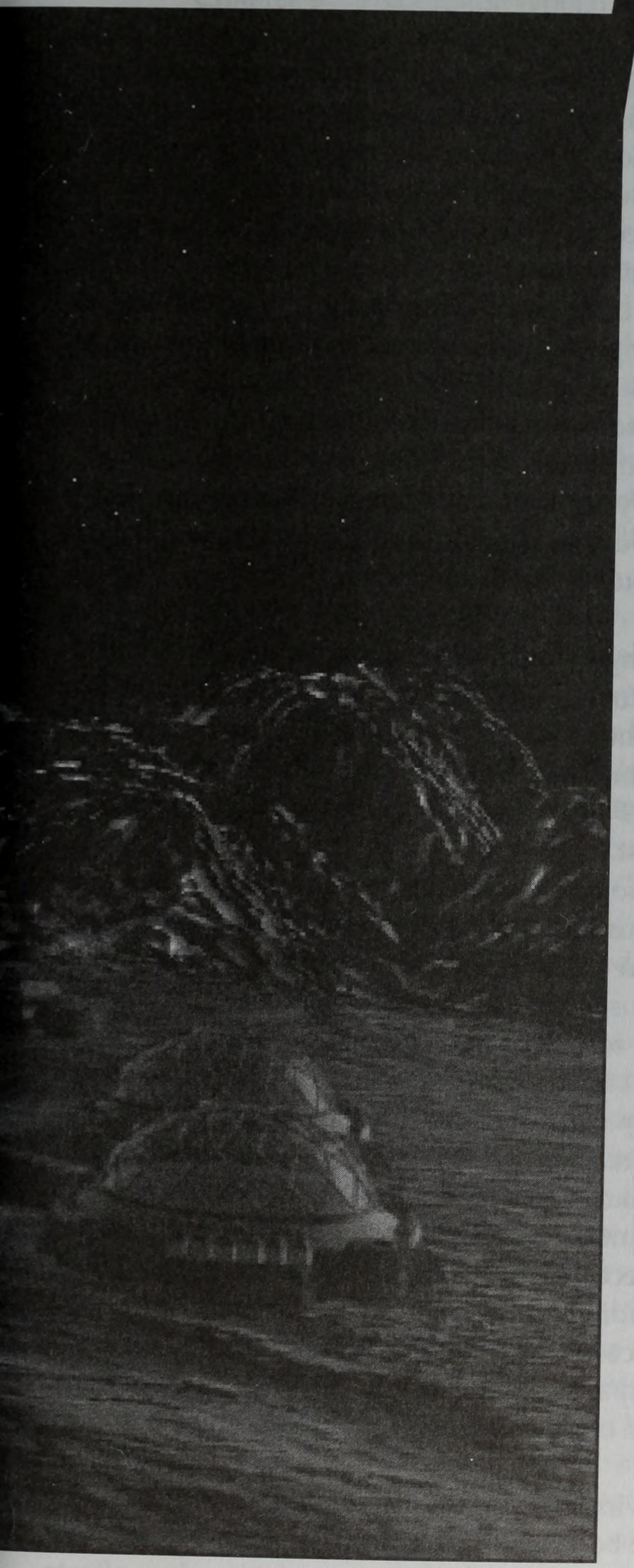


Figure 9-1 Surface structures are heavily shielded.



9

Structures: Would Frank Lloyd Wright Have Done It This Way?

A doctor can bury his mistakes, but an architect can only advise his client to plant vines.

Frank Lloyd Wright

In *Outpost*, the core of the game is the colony simulation itself. Data gathering and packing the ship merely set up the initial conditions for the simulation model. The simulation is manipulated through the construction of colony buildings, which you use to carry out your colony development and people management strategies. Be good to your colony; feed it, take care of it, watch it grow, and help it survive against the forces of a hostile planet. When the colony takes on a life of its own, developing into a mature city, you might feel like any proud parent who can point at their clever children and say, "look what I did."

This chapter goes into excruciating detail about the structures you can build, the requirements for building and maintaining them, placing structures to your best advantage, maximizing output while minimizing resource use, priorities for building, and the use of structures to manipulate your population.

Building Your Colony

When you start building your colony, survival is your first consideration. Although your needs will vary according to what you brought with you on the mothership and the local planetary environment, you should make sure that all your basic survival needs are covered. The Seed Factory can only get your colony started, so you have to do the rest.

What do you need for survival? You need mined resources to build and operate your structures. You need Closed Habitat Atmospheric Production (CHAP) Facilities to provide air to your buildings, because most of them are not self-contained. You need Agricultural Domes to feed your colonists, because they get grumpy when they're starving. You need a reliable source of power to satisfy your energy requirements. You need protected underground residential areas and other underground structures to minimize your population's exposure to cosmic radiation. You need a Disaster Instant Response Team (DIRT) to minimize the damage from unexpected events. The list goes on and on, with every structure depending on every other structure for its survival. Later in the game, once your survival needs are met, you can concentrate on tactical expansion, research, trade with other colonies, and the manipulation of your colonists for fun and profit.

The Key to the City

As each of the following structures is described, the statistics for each facility will also be given. Much of this information is available to you while playing the game, but some of it involves effects on the simulation model that you may not wish to know. Each listed building, referred to as a "tile," has the following input and output attributes.

Input

Number of versions of this tile: 1 to 3

When technology advances, many buildings become more efficient or productive. As new versions of a structure become available, the old version is replaced. This value shows how many versions of a particular structure exist in the game.

Number of turns required to build this tile: 0 to 9

Once a tile has been placed on a bulldozed surface, this value reflects the number of turns required to complete the building of the tile. You'll see the simulation (sim) construction workers active during this building phase. On completion, the tile becomes "active," making its production, research, or other capability available for use. Note that some structures, such as Nanotechnology Facilities, cannot be built until the appropriate research has been completed to make them available.

Energy required to build this tile: 0 to 6 (per turn)

This value reflects the Energy Class requirement necessary per turn to build the tile. This will usually be the normal operational Energy Class value + 1, reflecting the extra power necessary to assemble the structure. Energy can come from any of the distributed power sources: solar, geothermal, fusion, and so on.

Energy required to operate this tile: 0 to 5

This value reflects the Energy Class requirement necessary to operate the tile once it has been built and becomes "active," or available, whether or not it's actually being used. This value remains steady and is not dependent on anything else once the tile structure is built.

Population required to build this tile: Class 0 to 4

This value reflects the population requirement necessary per turn to build the tile. A population class is a variable amount of colonists determined internally by the simulation. This requirement can be met through the use of humans or robots.

Population required to operate this tile: Class 0 to 4

This value reflects the population requirement necessary to operate the tile once it has been built and becomes "active," whether or not it's actually being used. This value remains steady and is not dependent on anything else once the tile structure is completed. This requirement can be met through the use of humans or robots.

Resources required to build this tile: Any possible resource

This specifies which resources are required for the tile structure to be built. All structures require some form of Life Support (LSA, LSB, LSC) for the workers during construction (because most construction will be done with humans). Life Support A is also required underground for welding, even when there is an atmosphere already being pumped in from the CHAP facility. An explanation of the resources and the abbreviations used here can be found in Chapter 7.

Resources required to operate this tile: Any possible resource

This specifies which resources are required for the tile structure to function. For example, a smelter requires mined ore to work on. An explanation of the resources and the abbreviations used here can be found in Chapter 7.

Output

Morale effect: + or - up to 5 points

The Morale value is adjusted during each turn by a specified amount. Although it's rare for a tile to have a direct effect on the Morale value, certain tiles, such as the Commercial structure, allow the direct manipulation of colony morale, which has a moderating effect on everything else in the game.

Luxury effect: + or - up to 5 points

The Luxury value is adjusted during each turn by a specified amount. The main effect will be from the Light Industry Facility, which produces luxury goods. Luxury items are distributed to the population through Commercial structures as long as the supply lasts.

Manufactured Production effect: Product

This indicates what is produced by a particular structure, including research.

Special effects: Variable

This describes the Crime, Educational level, or other possible effects resulting from the presence of a specific active tile structure. If the structure produces useful SWG (sewage) for recycling, or factory RCY (recyclables), you'll also see that indicated.

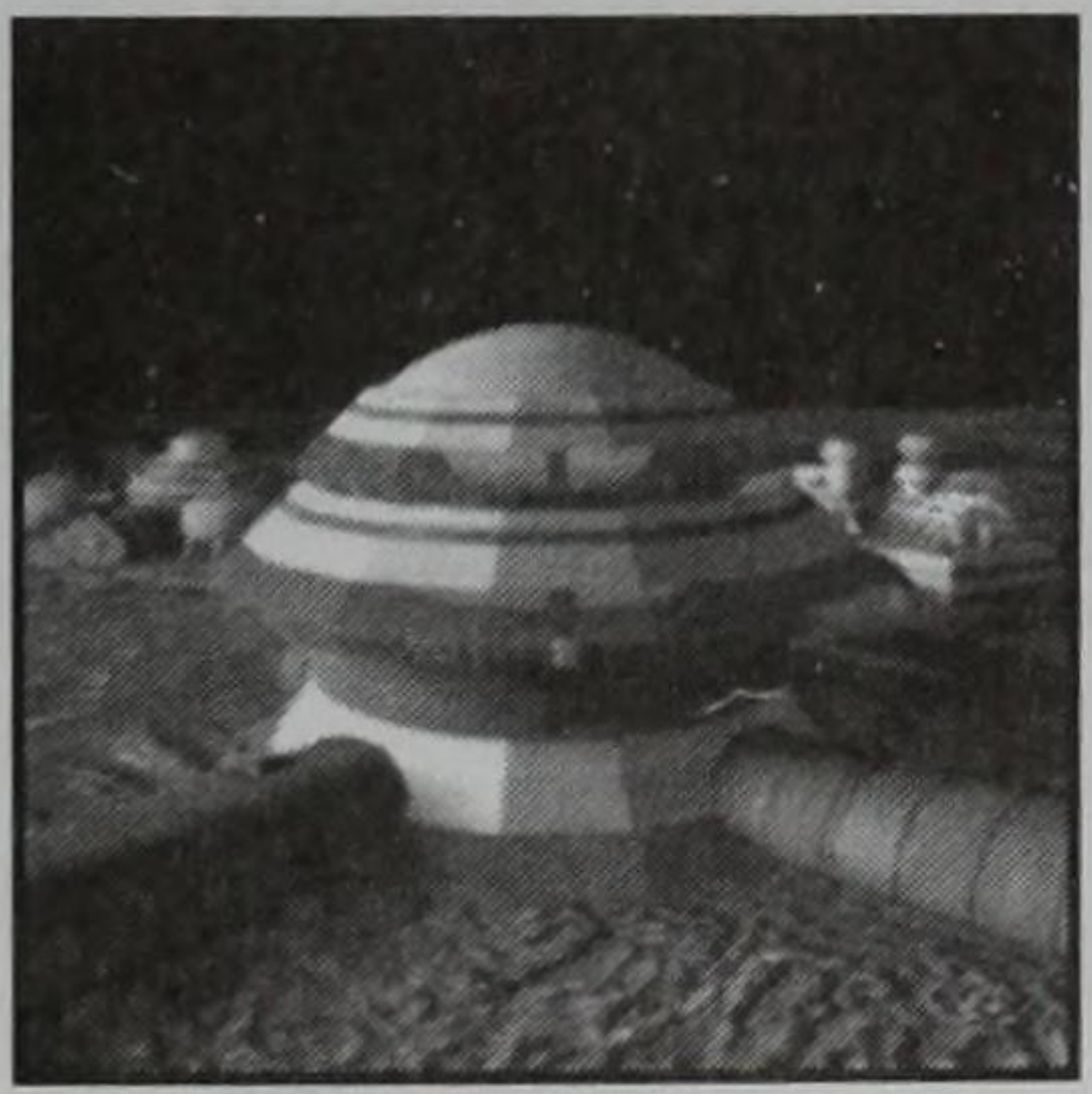
Percentage Chance of Breakdown: 0 to 50 percent
This value varies according to the hostility of the planet, the age of the structure, and other factors, but it specifies the percentage chance that a particular structure will break down and become inactive until it's repaired. This base figure is based on the complexity of the system involved.

Recycling value: 0 to 10
Recycling is an important activity in this game. This number reflects the value of the materials that can be recycled from a particular building. Because recycled materials are converted into multipurpose goo (MPG), which can replace almost any other resource in an emergency, you don't want to waste your waste.

Surface Structures

Surface structures are the sturdiest structures you can build. Not only must they be heavily shielded against cosmic radiation, but they must also be able to withstand incredible temperatures and pressures, as well as corrosive atmospheres. Surface buildings are exposed to the worst environmental aspects of a planet without any of the protection offered by being underground.

Administration/Trade Mission



The Trade Mission is an unusual structure, because it's actually built by your trading partner. If you open diplomatic relations with another colony, and your advances are accepted, your trading partner will offer to build a trade mission in his or her colony for you. They also provide the resources to build and maintain the trade mission. All you have to do is staff it with one person from your colony, after which you can engage in unlimited "free" trade with that colony.

Input

Number of versions of this tile:	1
Number of turns required to build this tile:	1
Energy required to build this tile:	2 (supplied by trade partner)
Energy required to operate this tile:	1 (supplied by trade partner)
Population required to build this tile:	1 (supplied by trade partner)
Population required to operate this tile:	1
Resources required to build this tile:	LSA, LSB, LSC PMA, PMC PRMA MA, MB (supplied by trade partner)
Resources required to operate this tile:	LSA, LSB, LSC (supplied by trade partner)

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	0
Recycling value:	0

Agricultural Dome

The Agricultural Dome is your food source. New research discoveries can enhance food production, but your main concern will be to keep your domes functioning to provide enough food for the current size of your population. The presence of a dome also increases morale, because the colonists can see that they aren't going to starve.

Input

Number of versions of this tile:	3
Number of turns required to build this tile:	5
Energy required to build this tile:	3
Energy required to operate this tile:	2
Population required to build this tile:	2
Population required to operate this tile:	1
Resources required to build this tile:	LSA, LSB, LSC PMA MA, MB, MC
Resources required to operate this tile:	LSA MA, MB, MC SWG

Output

Morale effect:	+1
Luxury effect:	0
Manufactured Production effect:	Food
Special effects:	0
Percentage Chance of Breakdown:	20
Recycling value:	5

CHAP Facility

The Closed Habitat Atmospheric Production (CHAP) Facility produces the basic life support gases your colonists need to survive, as well as by-products such as water. Air is provided to other structures from the CHAP Facility through the Tube system.

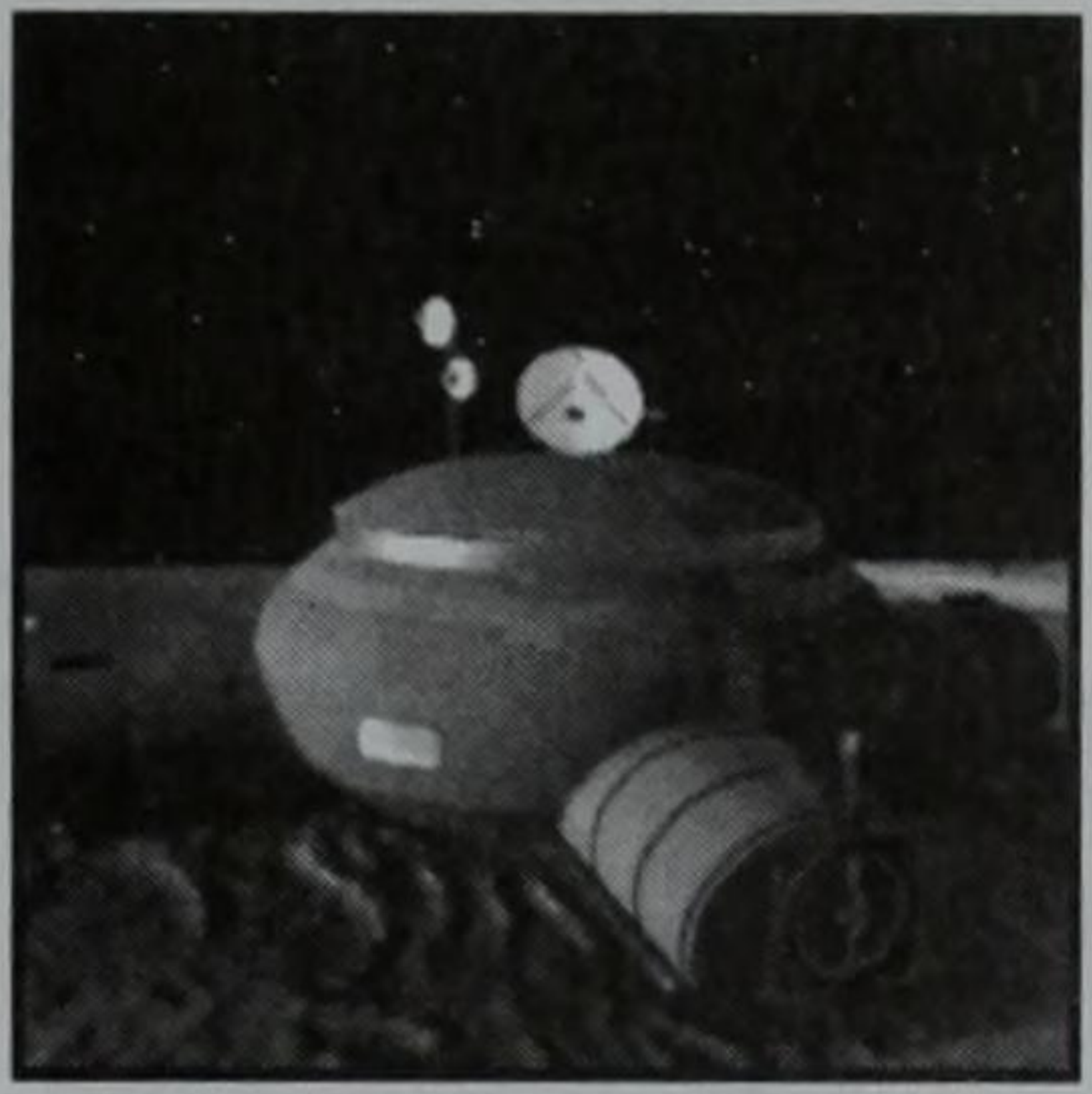
Input

Number of versions of this tile:	2
Number of turns required to build this tile:	6
Energy required to build this tile:	6
Energy required to operate this tile:	5
Population required to build this tile:	4
Population required to operate this tile:	4
Resources required to build this tile:	LSA, LSB, LSC PMA, PMC, PMD PRMA MA, MC
Resources required to operate this tile:	PRMA MA, MC

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	LSA, LSB, LSC
Special effects:	0
Percentage Chance of Breakdown:	10
Recycling value:	8

Command Center



The Command Center is a self-contained structure that serves as the core of any colony. Whereas the first one is built by the Seed Factory to provide a safe workshed and temporary living structure while the first colony is being built, new ones can be placed by you to create independent new colonies. Because Command areas can't overlap, you will be warned if you attempt to place a Command structure too close to an existing Command tile (as a general rule, a new one can't be within a 30-tile radius of an existing Command structure). Although the Command tile has its own battery power supply, it's a good idea to start mining operations in the area first, then bulldoze the location for your Command tile. After the new Command structure is built, a CHAP Facility will soon be needed to provide life support for the Command structure and your other new buildings that follow. The Command tile also houses the Engineering team, which can repair structures that are broken or due to break.

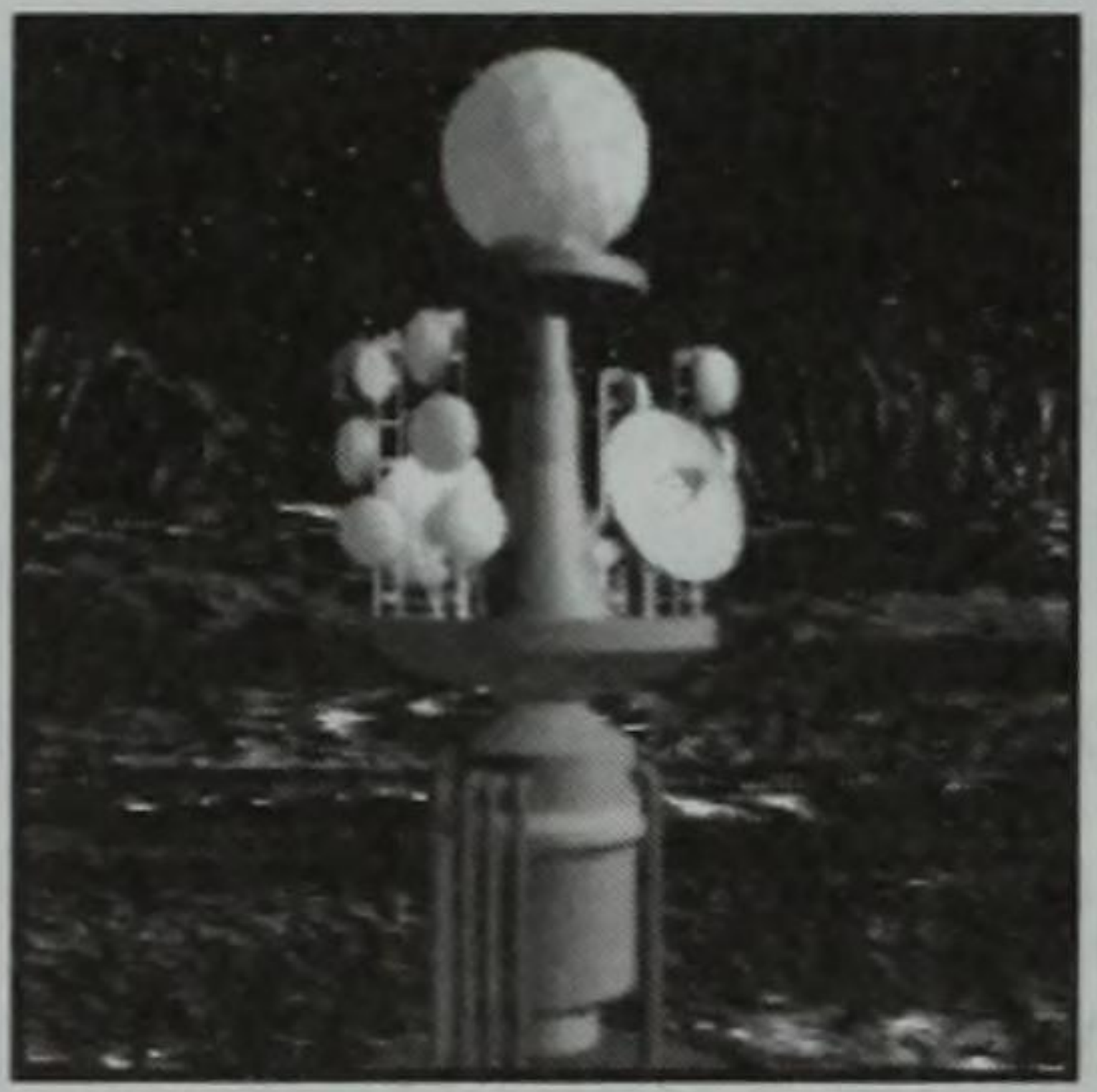
Input

Number of versions of this tile:	1
Number of turns required to build this tile:	3
Energy required to build this tile:	0
Energy required to operate this tile:	0
Population required to build this tile:	2
Population required to operate this tile:	1
Resources required to build this tile:	LSA, LSB, LSC PMA, PMC PRMA MA, MB
Resources required to operate this tile:	LSA, LSB, LSC

Output

Morale effect: 0
Luxury effect: 0
Manufactured Production effect: 0
Special effects: 0
Percentage Chance of Breakdown: 50
Recycling value: 7

Communications Tower



The Communications Tower keeps a colony in contact with its wide-ranging robots and with other colonies. Each tower has a limited range, so if your robots are wandering off never to be heard from again, try building some more towers further away from your colony.

Input

Number of versions of this tile: 3
Number of turns required to build this tile: 2
Energy required to build this tile: 5
Energy required to operate this tile: 4
Population required to build this tile: 2
Population required to operate this tile: 1
Resources required to build this tile: LSA, LSB, LSC
PMA, PMC
PRMB
MA
Resources required to operate this tile: LSA, LSB, LSC

Output

Morale effect: 0
Luxury effect: 0

Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	5
Recycling value:	3

DIRT Facility

The Disaster Instant Response Team (DIRT) Facility helps to minimize damage from unpredicted events that occur to your structures, such as meteorite strikes, explosions, and so on. The DIRT response area is limited, because the environment is hostile and bad things happen fast. On average, the DIRT Facility can protect structures in a 5-tile radius around itself. The closer a structure is to a DIRT team, the more likely it is to survive bad events with minimal damage.

Input

Number of versions of this tile:	2
Number of turns required to build this tile:	5
Energy required to build this tile:	5
Energy required to operate this tile:	4
Population required to build this tile:	3
Population required to operate this tile:	2
Resources required to build this tile:	LSA, LSB, LSC PMA, PMB, PMC, PMD PRMA MA, MB
Resources required to operate this tile:	LSA, LSB, LSC PMA, PMB, PMC, PMD PRMA MA, MB

Output

Morale effect: +1
Luxury effect: 0
Manufactured Production effect: 0
Special effects: 0
Percentage Chance of Breakdown: 0
Recycling value: 8

Factory

Although factory functions are described in detail in Chapter 10, these surface factories can produce robots, robot spare parts, road material, and other potentially toxic materials that are not allowed into the underground environment. As with other surface structures, the factory is heavily shielded, but must be evacuated to keep the workers safe during solar flares.

Input

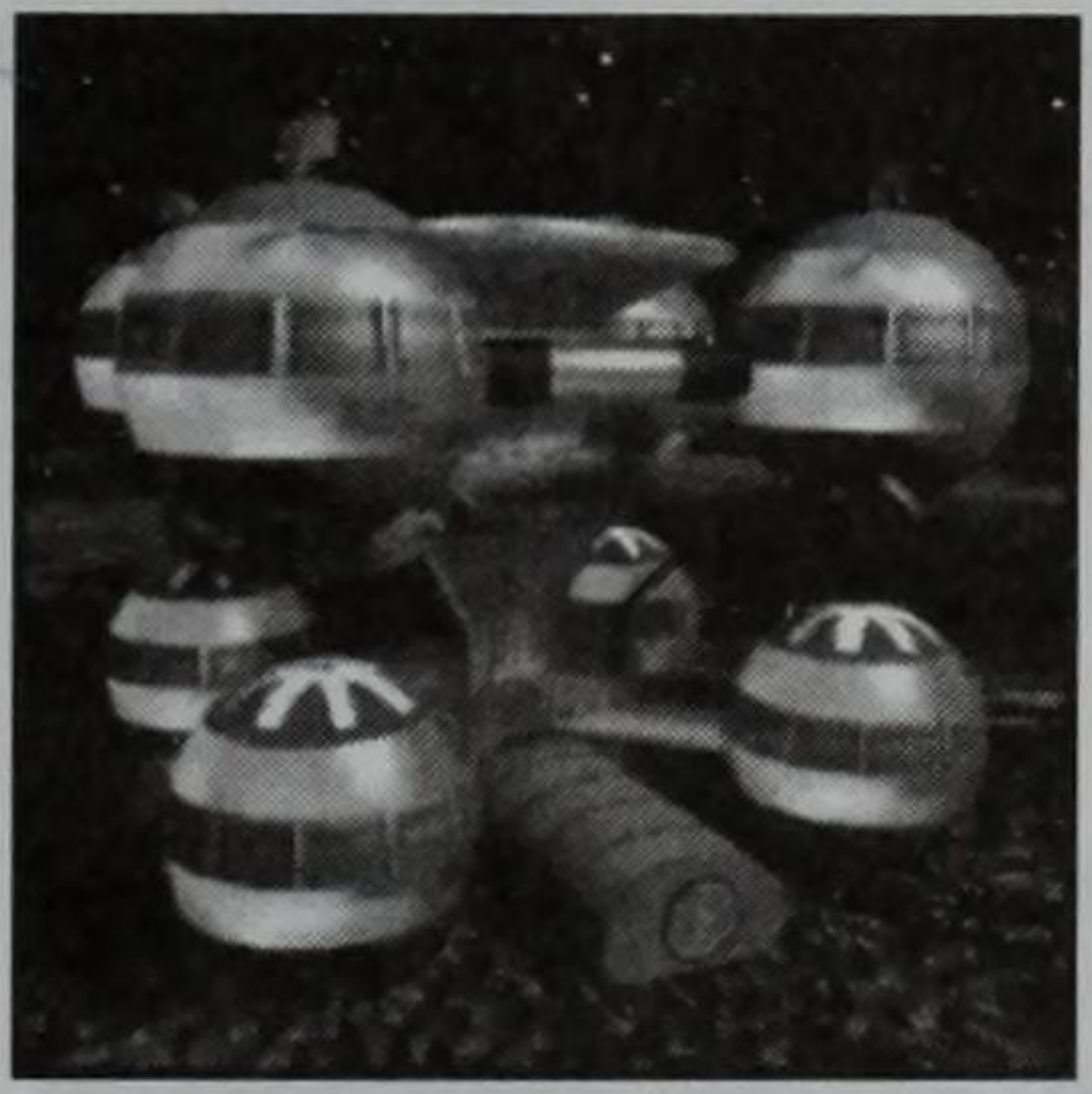
Number of versions of this tile: 3
Number of turns required to build this tile: 6
Energy required to build this tile: 6
Energy required to operate this tile: 5
Population required to build this tile: 2
Population required to operate this tile: 1
Resources required to build this tile: LSA, LSB, LSC
PMA, PMB, PMC, PMD
PRMA, PRMB
MA, MB, MC
FEA

Resources required to operate this tile:	PMA, PMB, PMC, PMD PRMA, PRMB MA, MB, MC FEA

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	Robots, robot spare parts, roads, fuel cells
Special effects:	+1 RCY (recyclables)
Percentage Chance of Breakdown:	10
Recycling value:	8

Hot Laboratory



The Hot Laboratory is designed to house potentially dangerous experiments. As such, it is prone to the occasional explosion that may penetrate the containment vessels, which is why the structure is composed of several different experimental areas located on the surface of the colony.

Input

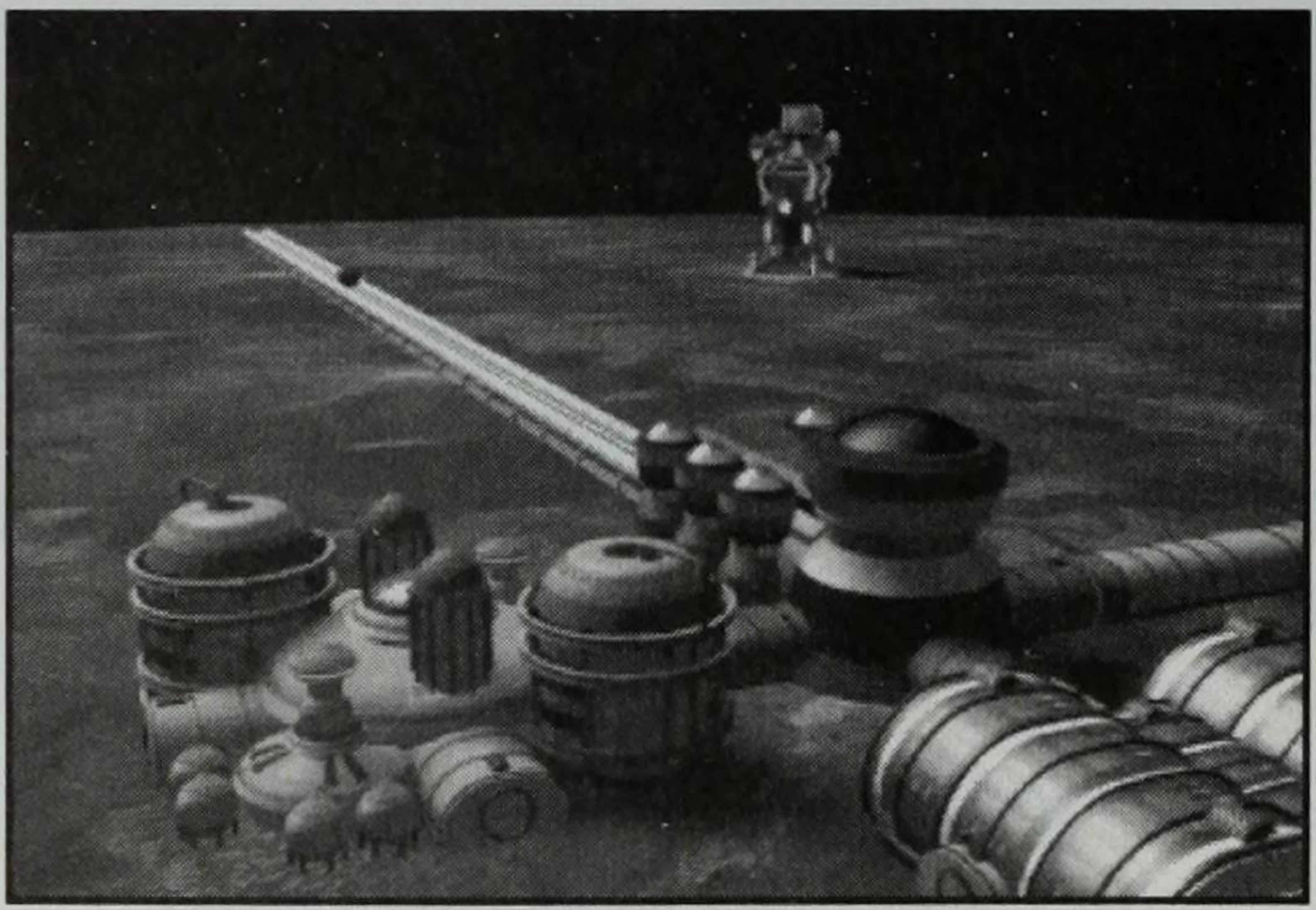
Number of versions of this tile:	2
Number of turns required to build this tile:	5
Energy required to build this tile:	5
Energy required to operate this tile:	4
Population required to build this tile:	3
Population required to operate this tile:	2

Resources required to build this tile:	LSA, LSB, LSC PMA, PMB, PMC, PMD PRMA, PRMB MA, MB, MC FEA, FEB
Resources required to operate this tile:	LSA PMA, PMB PRMA, PRMB MA, MB, MC

Output

Morale effect:	-1 (workers nervous)
Luxury effect:	0
Manufactured Production effect:	Research
Special effects:	+1 SWG
Chance of explosion:	50
Percentage Chance of Breakdown:	20
Recycling value:	5

Mass Driver



The Mass Driver is an electromagnetic rail gun designed to launch payloads into orbit, where they're caught by a big net. Resources are the most common payload, making it easier to build large spacecraft in orbit without having to run freighters back and forth with smaller loads.

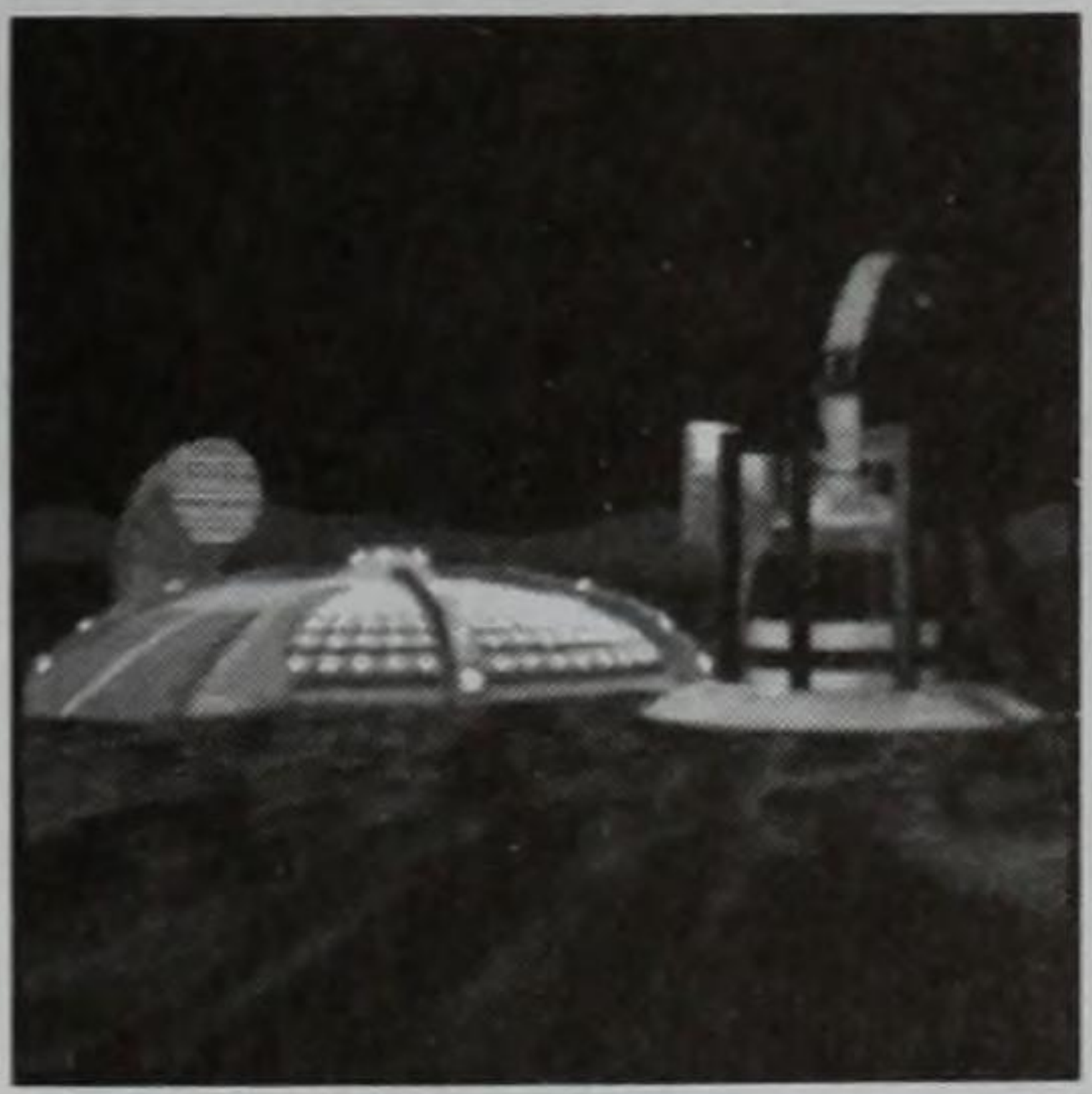
Input

Number of versions of this tile:	1
Number of turns required to build this tile:	9 per segment
Energy required to build this tile:	6
Energy required to operate this tile:	5
Population required to build this tile:	4
Population required to operate this tile:	4
Resources required to build this tile:	LSA, LSB, LSC PMA, PMB, PMC, PMD PRMA, PRMB FEB MA, MB, MC
Resources required to operate this tile:	PMA, PMB, PMC, PMD PRMA

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	20
Recycling value:	5

Mine (Active)



Once a robominer has dug at least one level of a mine, the Active Mine tile appears on the surface to mark the mine's location. Details on mining are given in Chapter 7. It's important to be aware of mine and colony locations, both on the surface and underground, because it is possible for a robominer to dig its way down into an active subterranean level of your colony, which has unfortunate side effects. Mined ore is stored at the surface until a monorail or trucks arrive to pick up the load for transport to the Smelter.

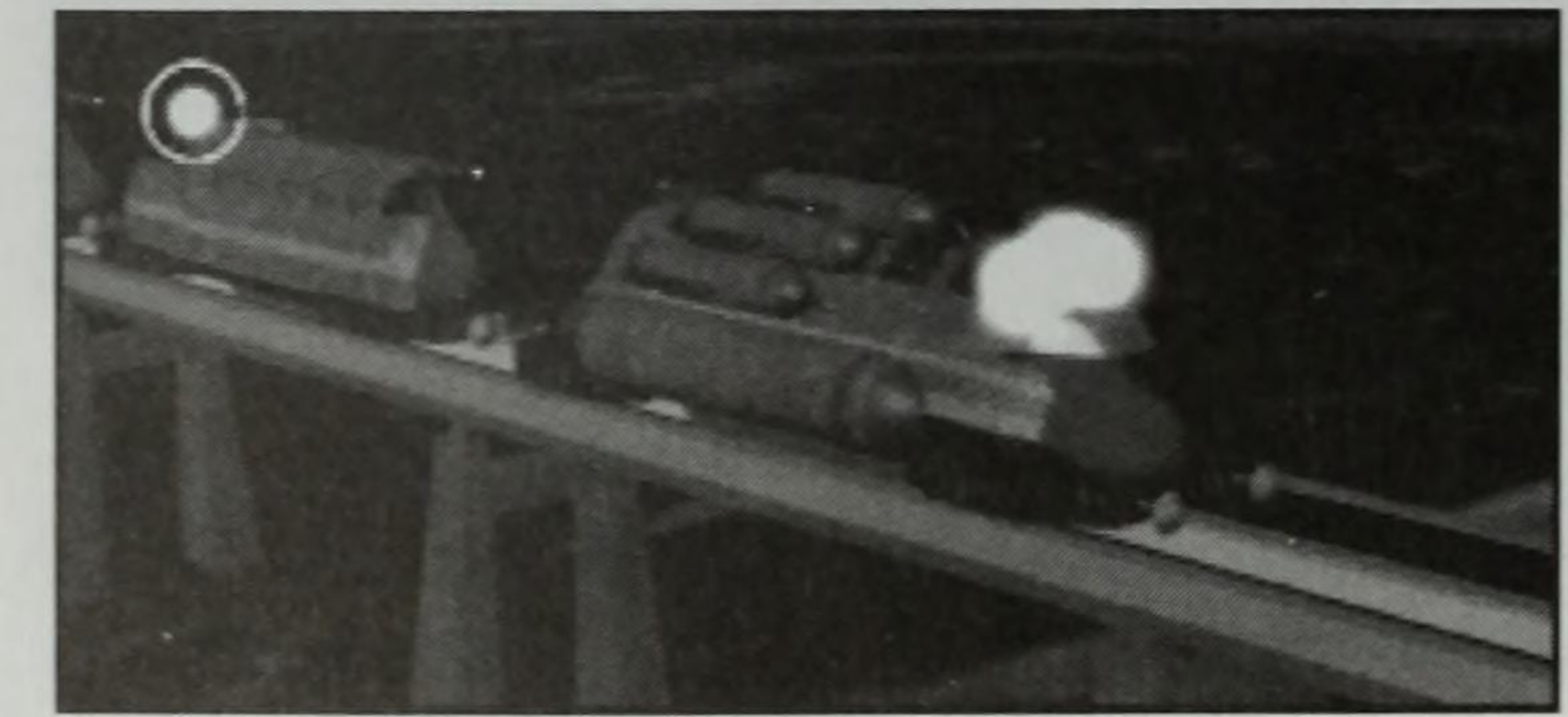
Input

Number of versions of this tile:	2
Number of turns required to build this tile:	7
Energy required to build this tile:	6
Energy required to operate this tile:	5
Population required to build this tile:	2
Population required to operate this tile:	1
Resources required to build this tile:	LSA, LSB, LSC PMA MA
Resources required to operate this tile:	LSA, LSB, LSC

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	Mined ore
Special effects:	0
Percentage Chance of Breakdown:	30
Recycling value:	5

Monorail



Able to carry mined ore, resources, or passengers, the Monorail is expensive to build, moderately expensive to operate, but fast and efficient at moving large loads. Monorails are used to connect mines to Smelters and colonies to other colonies.

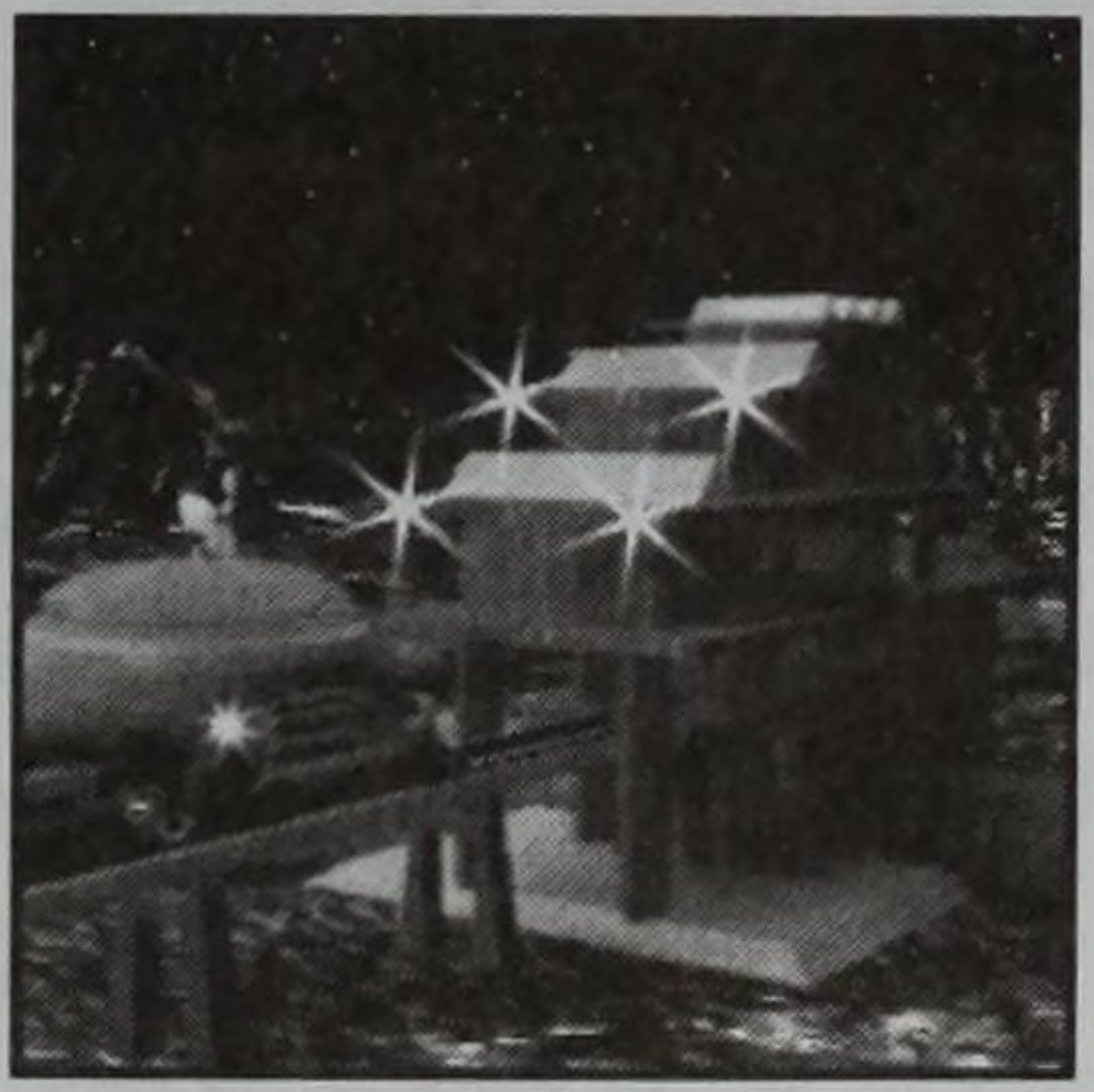
Input

Number of versions of this tile:	1
Number of turns required to build this tile:	7 per segment
Energy required to build this tile:	5
Energy required to operate this tile:	4
Population required to build this tile:	2
Population required to operate this tile:	1
Resources required to build this tile:	LSA, LSB, LSC PMA, PMB, PMC, PMD MA, MB, MC
Resources required to operate this tile:	LSA, LSB

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	30
Recycling value:	2

Monorail Station



A Monorail Station is required at each terminal end of a monorail line. The station has facilities for passengers and for cargo handling.

Input

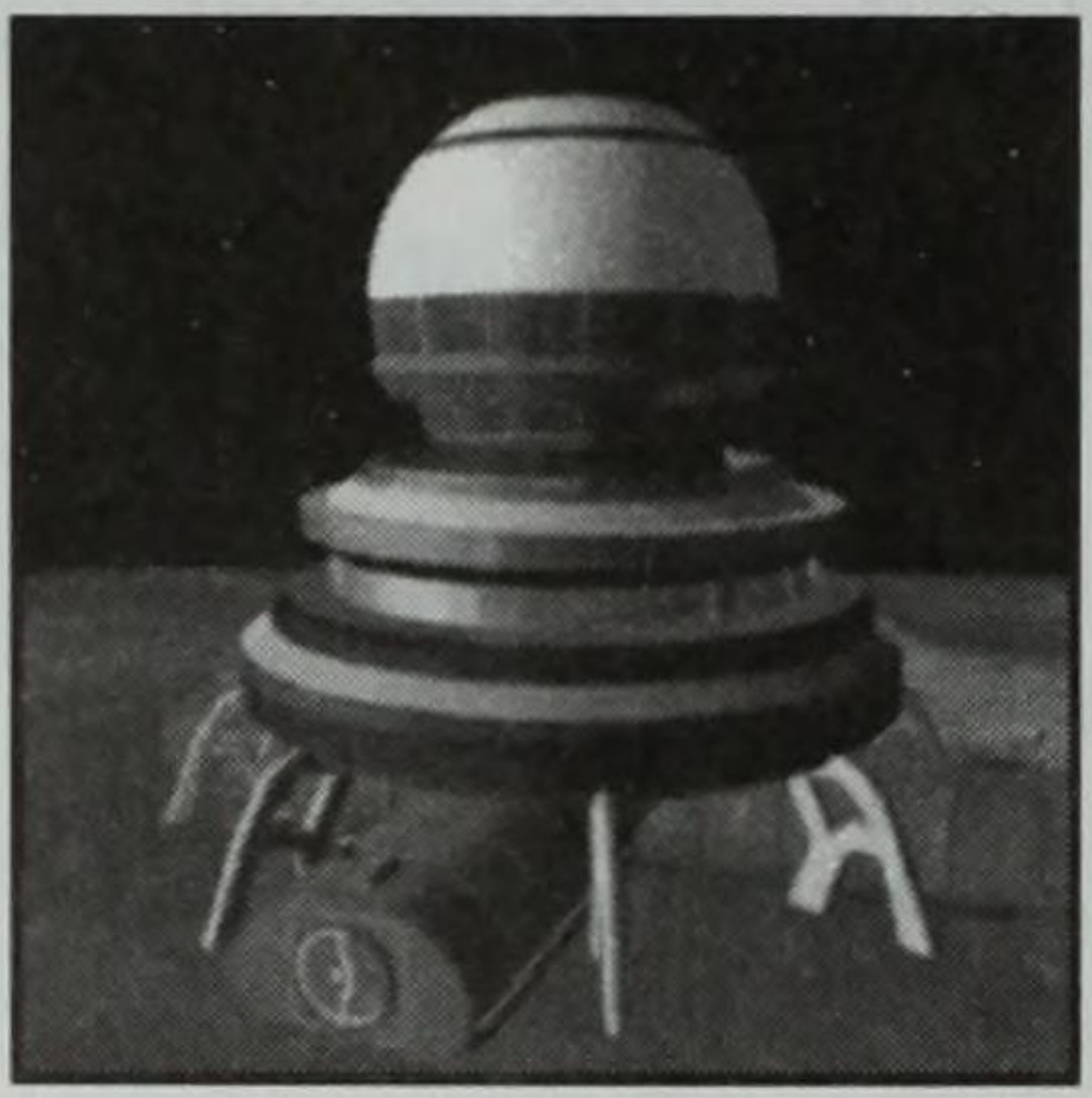
Number of versions of this tile:	1
Number of turns required to build this tile:	6
Energy required to build this tile:	4
Energy required to operate this tile:	3

Population required to build this tile:	2
Population required to operate this tile:	1
Resources required to build this tile:	LSA, LSB, LSC PMA, PMB, PMC, PMD MA, MB, MC
Resources required to operate this tile:	LSA, LSB

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	30
Recycling value:	2

Nanotechnology Facility



As soon as nanotechnology has been discovered through extensive research, and the capability to create a Nanotechnology Facility is generated, it's a good idea to build at least one in each colony you own. As soon as this facility is completed, resources will no longer be a limiting factor to the growth of your colony. Nanotechnology is explained in more detail in Chapter 25.

Input

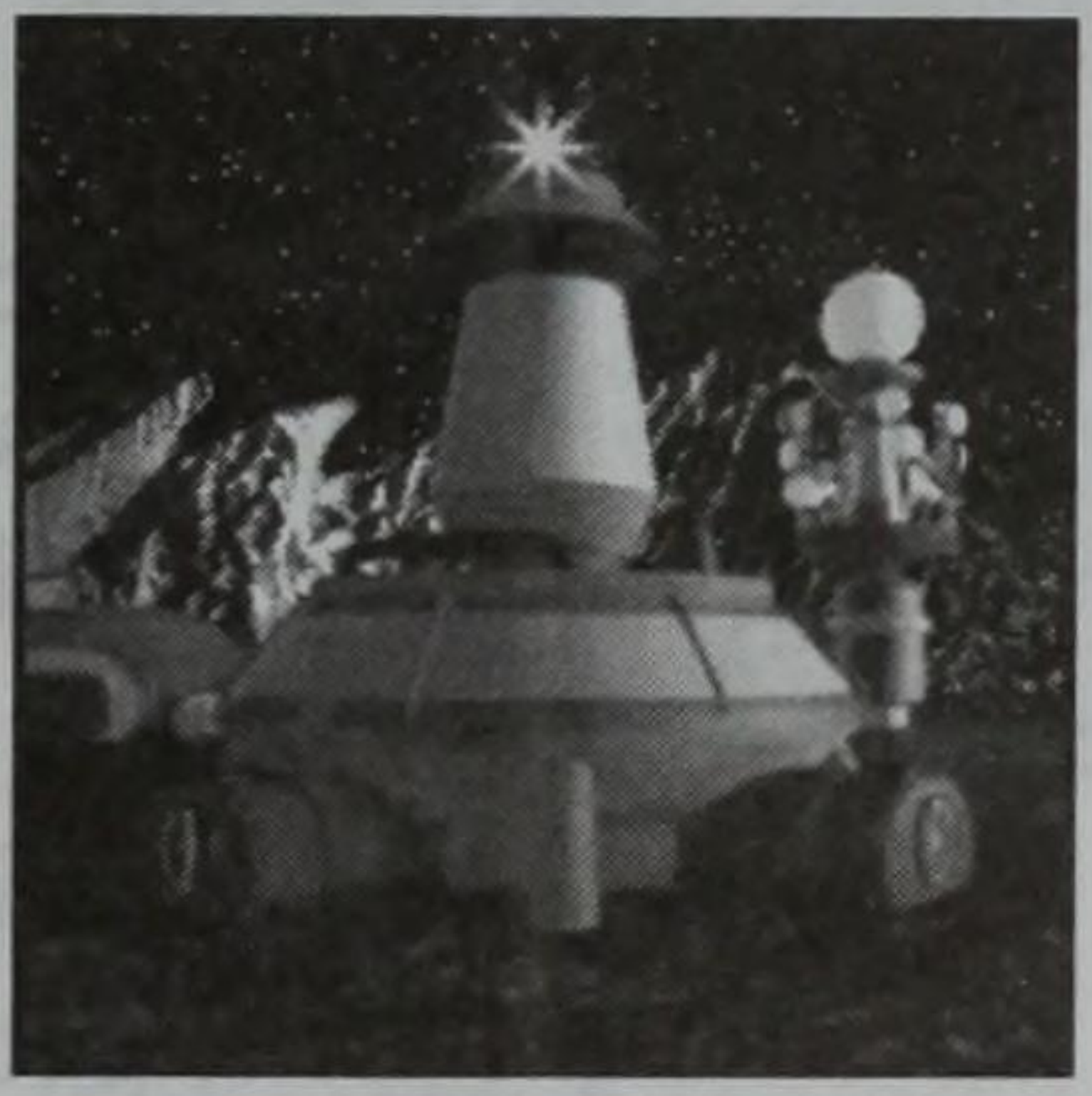
Number of versions of this tile:	1
Number of turns required to build this tile:	5
Energy required to build this tile:	4
Energy required to operate this tile:	3
Population required to build this tile:	3
Population required to operate this tile:	2

Resources required to build this tile:	LSA, LSB, LSC PMA, PMB, PMD PRMA, PRMB MA, MB, MC
Resources required to operate this tile:	MA, MB, MC PRMA, PRMB

Output

Morale effect:	+1
Luxury effect:	+1
Manufactured Production effect:	Removes resource requirements
Special effects:	0
Percentage Chance of Breakdown:	20
Recycling value:	5

Police Station



When a Police Station is placed on the map, you can choose the attitude you'd like your human or robot police to use on the local population. "Benevolent" police reduce the Crime level by half in a radius of five tiles surrounding the Police Station, while improving the Morale level by 1 point per turn. "Hostile" police reduce the Crime level to zero in a radius of five tiles, but the Morale level is also reduced by 1 point per turn.

Input

Number of versions of this tile:	2
Number of turns required to build this tile:	4 surface, 3 underground
Energy required to build this tile:	4
Energy required to operate this tile:	3
Population required to build this tile:	3

Population required to operate this tile:	2
Resources required to build this tile:	LSA, LSB, LSC PMA, PMB, PMD MA
Resources required to operate this tile:	PMA, PMB MA

Output

Morale effect:	+1 or -1 based on Attitude setting
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	Crime level (see description)
Percentage Chance of Breakdown:	20
Recycling value:	3

Road

A Road is built with road material produced from your surface factories. The process of building a Road is described in Chapter 12, and the process of making road material is described in Chapter 10. A union road-building crew of six people is required to drive the road-making machine, block traffic, prepare the already bulldozed surface, set up safety lights, set up work lights, take down the safety lights, take down the work lights, and take up to 23 work breaks over the course of 2 game turns. On some planets, Roads decay quickly due to the hostile environment, so they must be replaced.

Input

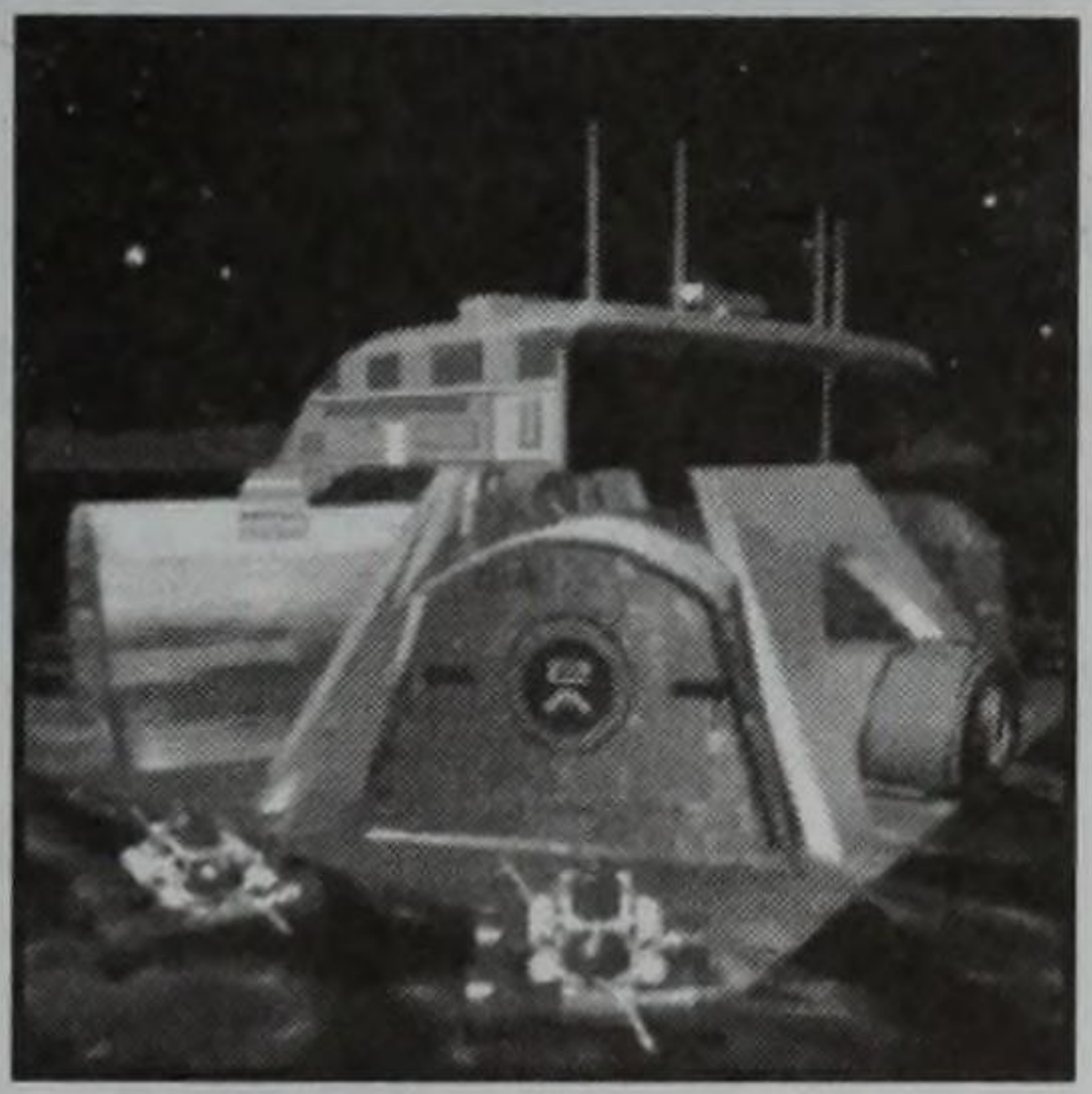
Number of versions of this tile:	3 different directions
Number of turns required to build this tile:	2
Energy required to build this tile:	0
Energy required to operate this tile:	0
Population required to build this tile:	6
Population required to operate this tile:	0

Resources required to build this tile:	LSA, LSB, LSC PMA Road material (from factory)
Resources required to operate this tile:	0

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	0
Recycling value:	1

Robot Command



Robot Command is your centralized robot control facility, which issues orders and maintains contact with your explorers, robominers, repairbots, and other wandering robots. If a robot's fuel cell fails in the field, Robot Command will receive an alert so that a repairbot can be dispatched to make repairs. All robot control functions are handled from this location, working closely with the Communications Tower signal relays.

Input

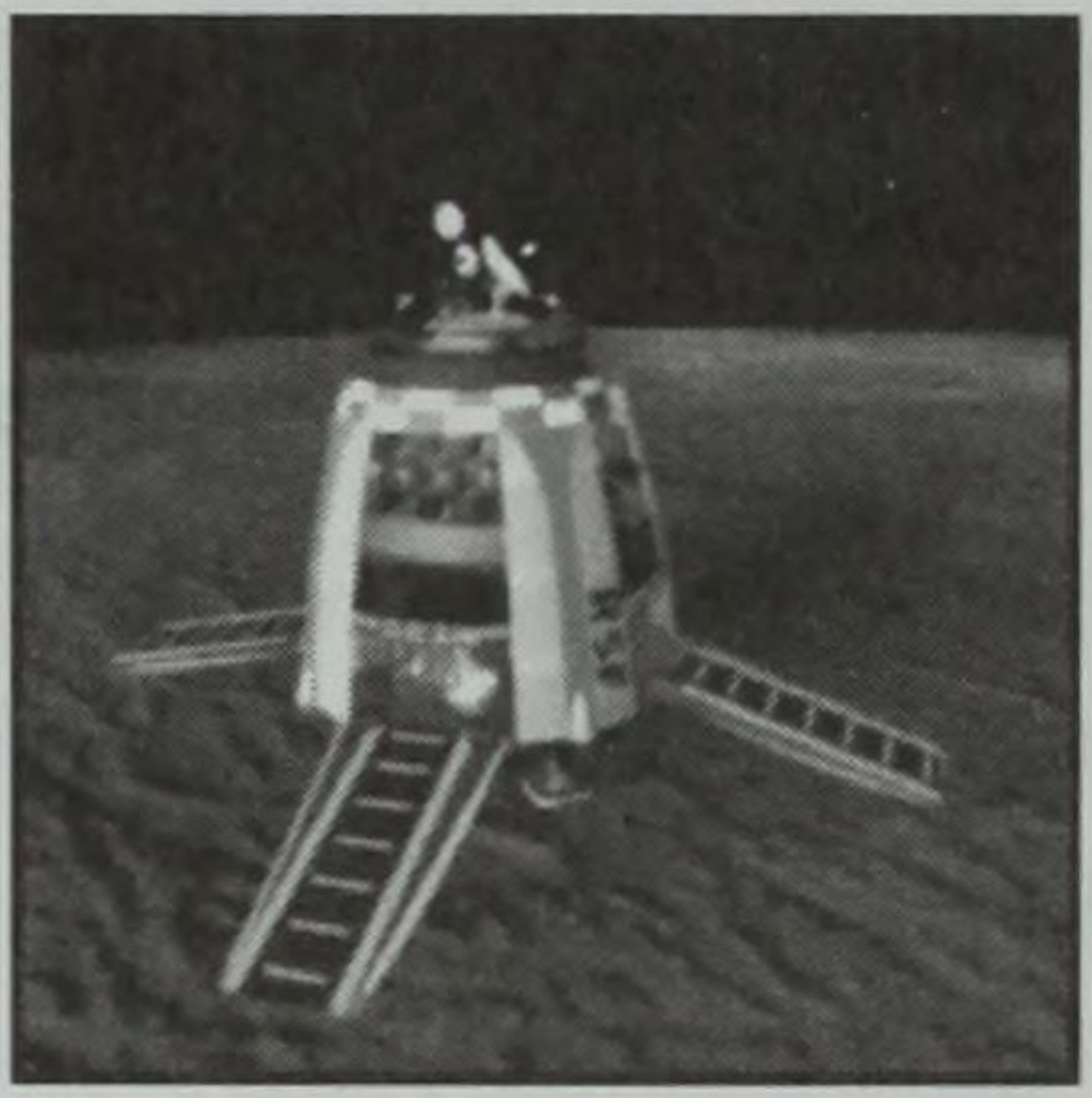
Number of versions of this tile:	2
Number of turns required to build this tile:	3
Energy required to build this tile:	4
Energy required to operate this tile:	3
Population required to build this tile:	2
Population required to operate this tile:	1

Resources required to build this tile:	LSA, LSB, LSC PMA, PMC PRMA MA, MB
Resources required to operate this tile:	LSA, LSB, LSC

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	30
Recycling value:	7

Seed Factory



The Seed Factory, described in detail in its own Chapter 6, is a sophisticated form of automated factory that lands on the planet before the humans arrive, preparing the landing site for colonization. It has a limited number of special capabilities, such as robot production and ore processing, which make it a multipurpose facility. The original Command structure is also generated by the Seed Factory.

Input

Number of versions of this tile:	1
Number of turns required to build this tile:	2
Energy required to build this tile:	0
Energy required to operate this tile:	0
Population required to build this tile:	0
Population required to operate this tile:	0
Resources required to build this tile:	0
Resources required to operate this tile:	0

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	Robots
Special effects:	Self-replicating
Percentage Chance of Breakdown:	0
Recycling value:	10

Smelter/Ore Processing Facility

The Smelter/Ore Processing Facility is described in detail in Chapter 7. This is where trucks or monorails transport mined ore for processing into useful resources. It has a limited storage capability, so processed resources must be moved to colony storage tanks on a regular basis.

Input

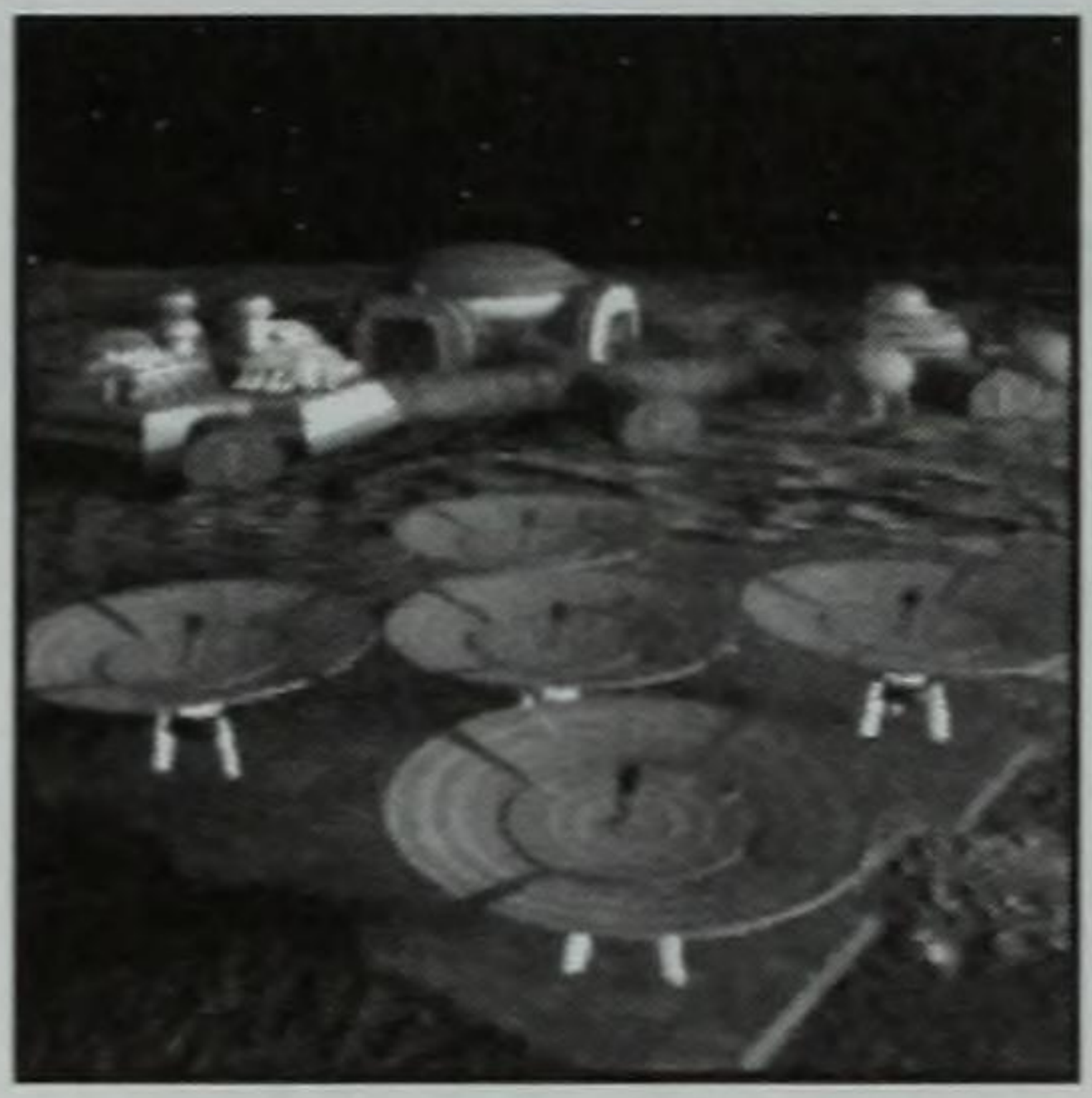
Number of versions of this tile:	2
Number of turns required to build this tile:	7
Energy required to build this tile:	6
Energy required to operate this tile:	5
Population required to build this tile:	4
Population required to operate this tile:	3
Resources required to build this tile:	LSA, LSB, LSC PMA, PMB, PMC, PMD MA, MB, MC
Resources required to operate this tile:	PMA, PMB, PMC, PMD MA, MB, MC

Output

Morale effect:	0
Luxury effect:	0

Manufactured Production effect:	Processed resources
Special effects:	0
Percentage Chance of Breakdown:	10
Recycling value:	8

Solar Powersat Receiver Array



The Solar Powersat Receiver Array, also known as a rectenna, is necessary to produce power from the focused microwave energy beamed down to the surface from a powersat. If no powersats are in orbit, these are not necessary. Up to two receiver arrays can be used per powersat to make full use of the microwave beam.

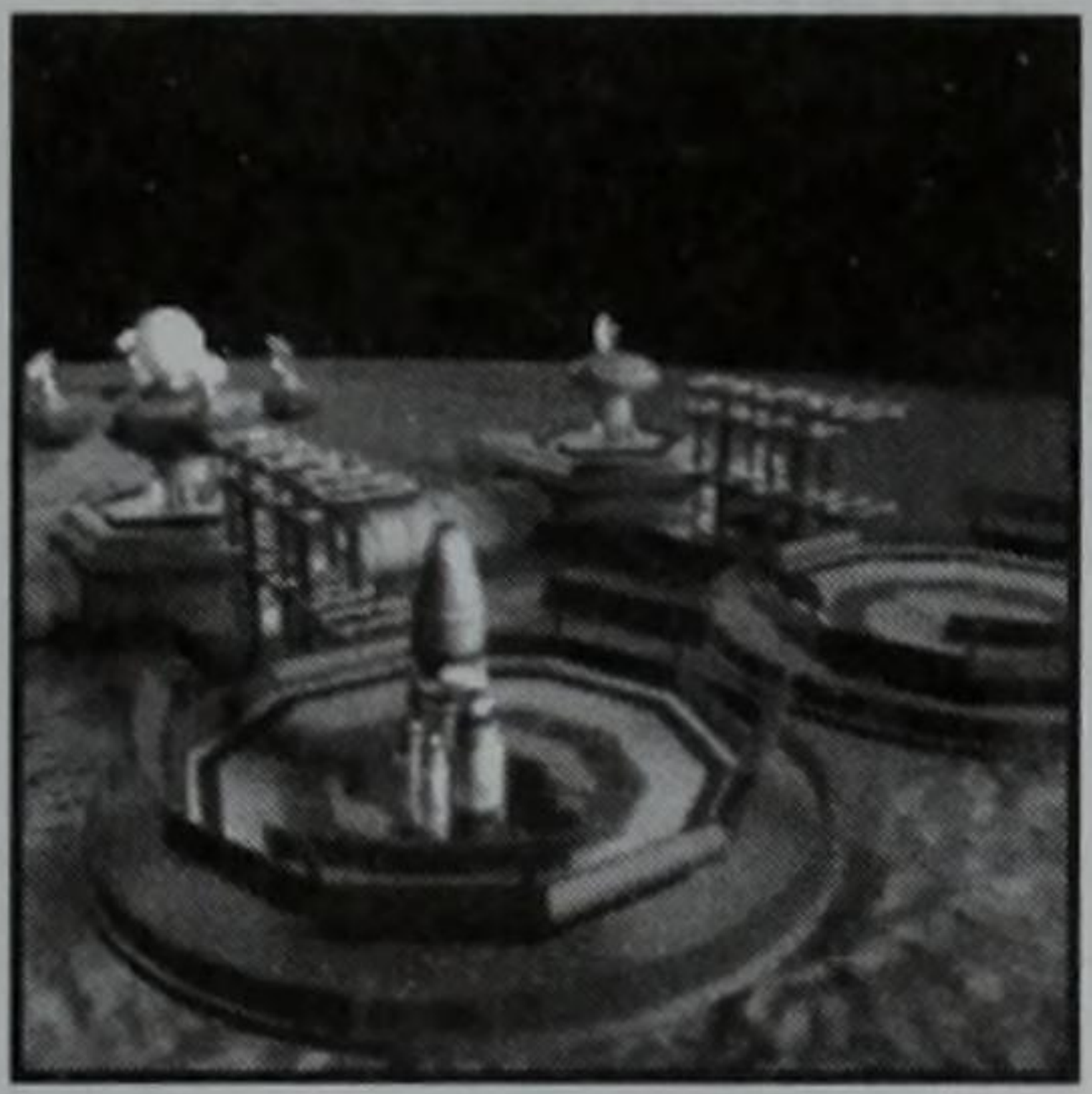
Input

Number of versions of this tile:	1
Number of turns required to build this tile:	4
Energy required to build this tile:	2
Energy required to operate this tile:	1
Population required to build this tile:	2
Population required to operate this tile:	1
Resources required to build this tile:	LSA, LSB, LSC PMA, PMB, PMD PRMA, PRMB MA
Resources required to operate this tile:	0

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	Power
Special effects:	0
Percentage Chance of Breakdown:	20
Recycling value:	7

Spaceport



When the space program and heavy lifter capabilities have been developed through research, a Spaceport can be built to launch cargo or satellites into orbit. Low-orbit freighters can be used to transport cargo to other colonies on the surface of the planet. The Spaceport also has a cavernous underground warehouse portion for storing satellites, heavy lifters, and freighters until you need to use them.

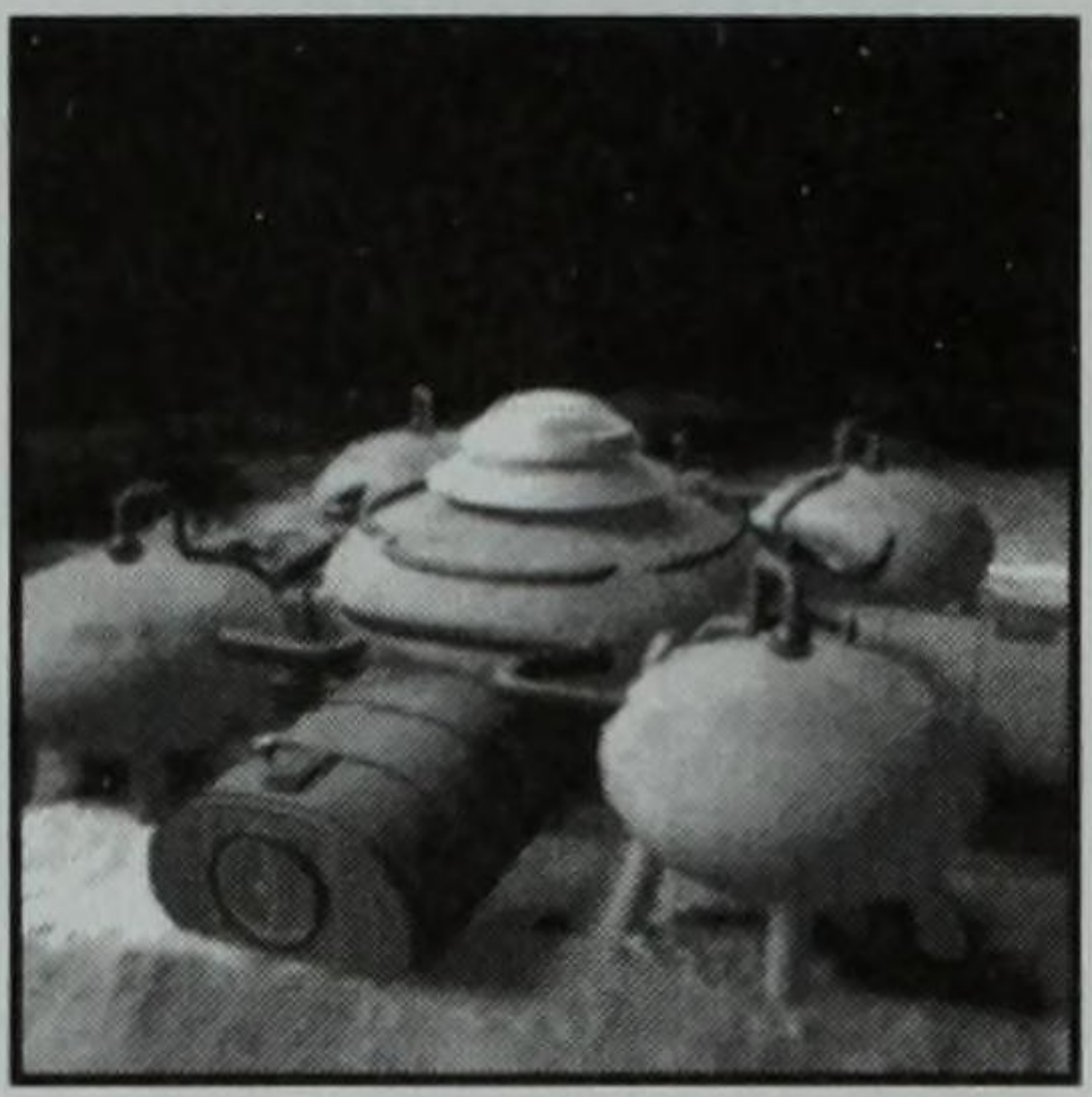
Input

Number of versions of this tile:	1
Number of turns required to build this tile:	7
Energy required to build this tile:	6
Energy required to operate this tile:	5
Population required to build this tile:	4
Population required to operate this tile:	4
Resources required to build this tile:	LSA, LSB, LSC PMA, PMD MA, MB, MC PRMA
Resources required to operate this tile:	PRMA FEA MA

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	30
Recycling value:	10

SPEW Facility



The Sewage Processing and Environmental Waste (SPEW) Facility is the recycling center for your colony. Sewage and recyclables are shipped to the SPEW Facility on a regular basis for processing into a very useful resource known as multipurpose goo (MPG). Bulldozed structures are also shipped to the SPEW so that their valuable materials can be reclaimed. It's a good idea to build one of these early in your colony's development to make up for the lack of any local resources that might be limiting your building program. The colonists are aware of the importance of recycling, so their morale also improves when you build a SPEW.

Input

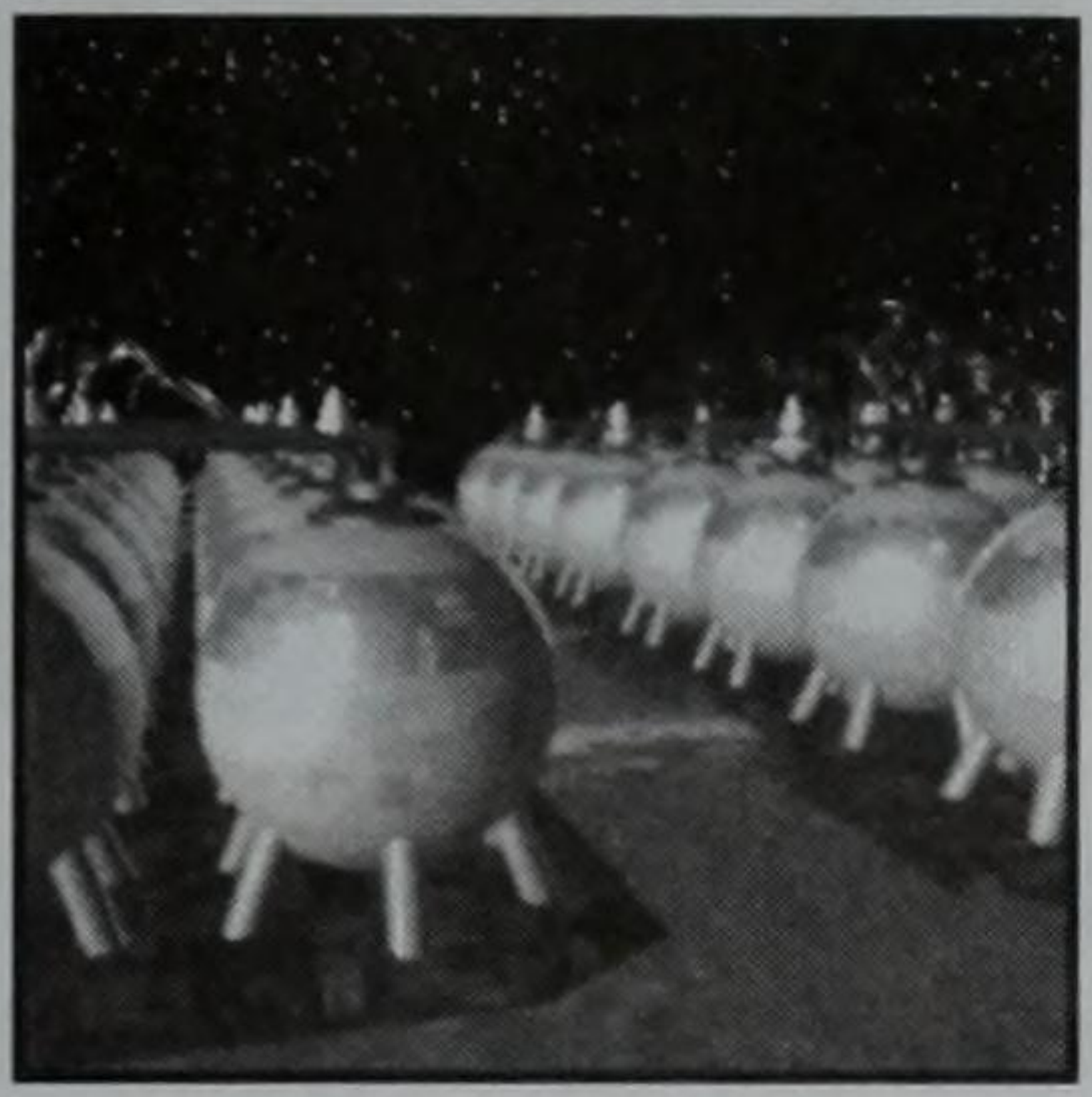
Number of versions of this tile:	3
Number of turns required to build this tile:	8
Energy required to build this tile:	4
Energy required to operate this tile:	3
Population required to build this tile:	3
Population required to operate this tile:	2
Resources required to build this tile:	LSA, LSB, LSC PMA, PMC, PMD MA, MB, MC
Resources required to operate this tile:	LSA, LSB, LSC MA, MB, MC SWG or RCY

Output

Morale effect:	+1
Luxury effect:	0
Manufactured Production effect:	MPG
Special effects:	0

Percentage Chance of Breakdown:	40
Recycling value:	7

Storage Tanks



Storage Tanks are an important early addition to your colony, because they serve as the delivery point for all of your mine resources that have been processed for use. Until the resources are in your Storage Tanks, they are not available to the colony for building and maintenance of your structures. Either trucks or monorails can deliver the resources to your Storage Tanks, which can hold 1,000 units of any resource.

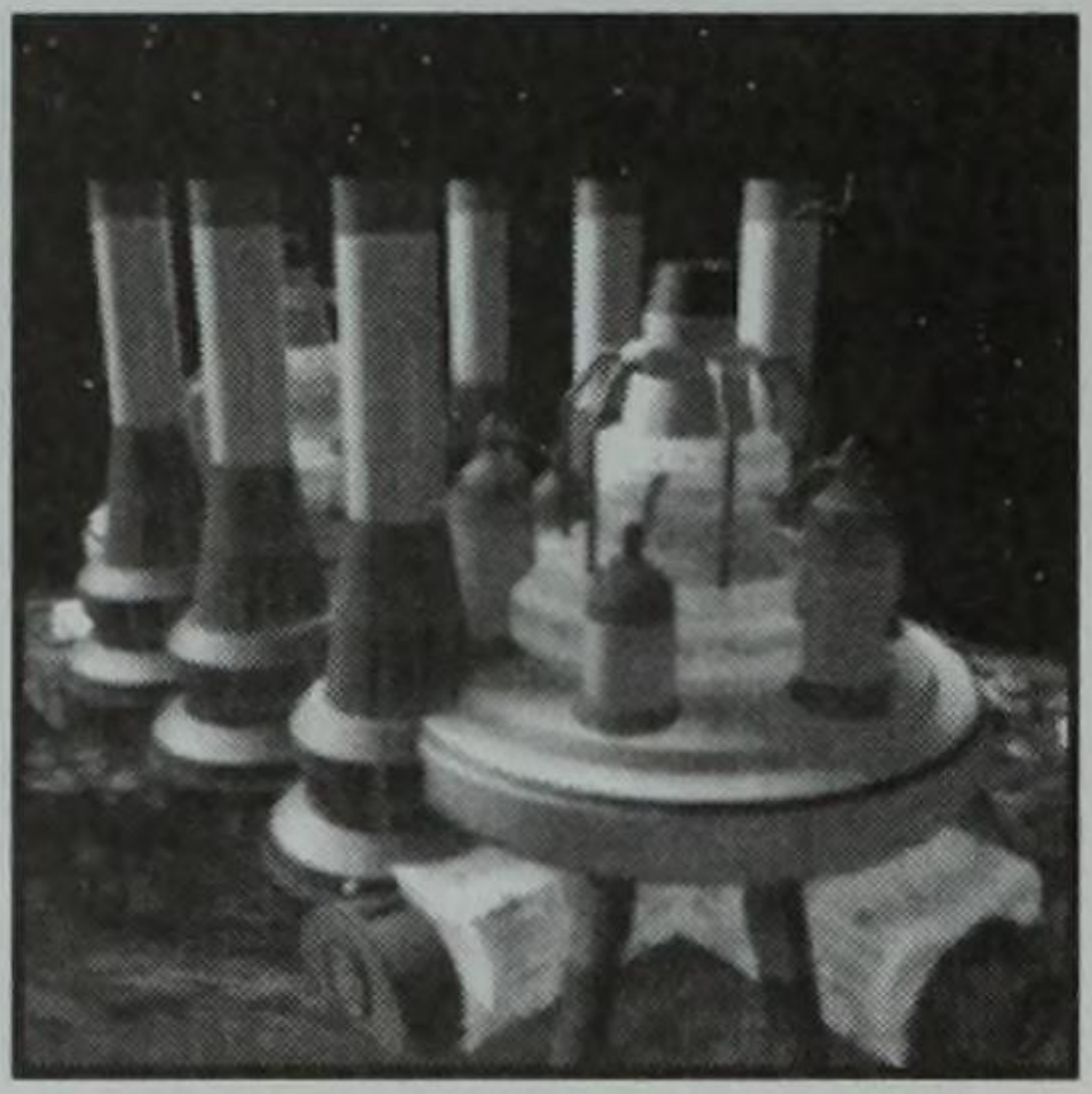
Input

Number of versions of this tile:	2
Number of turns required to build this tile:	2
Energy required to build this tile:	2
Energy required to operate this tile:	1
Population required to build this tile:	1
Population required to operate this tile:	0
Resources required to build this tile:	LSA, LSB, LSC PMA, PMB
Resources required to operate this tile:	0

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	0
Recycling value:	2

Terraforming Facility



The Terraforming Facility, not to be confused with the CHAP Facility, is used to create a breathable atmosphere (BA) for your entire planet. Considerable research must be performed before this structure becomes available for you to build late in the game. You can read more about terraforming in Chapter 23. This tile provides a major Morale bonus for your population, as well as a small Luxury bonus.

Input

Number of versions of this tile:	2
Number of turns required to build this tile:	9
Energy required to build this tile:	6
Energy required to operate this tile:	5
Population required to build this tile:	4
Population required to operate this tile:	4
Resources required to build this tile:	LSA, LSB, LSC PMA, PMB, PMC, PMD PRMA, PRMB MA, MB, MC, MD
Resources required to operate this tile:	LSA MA, MB, MC

Output

Morale effect:	+5
Luxury effect:	+1
Manufactured Production effect:	BA
Special effects:	0
Percentage Chance of Breakdown:	20
Recycling value:	9

Tokamak Fusion Reactor

On a planet that's far from its primary star, the Tokamak Fusion Reactor will usually be your primary source of power for your colony structures. Discussed in detail in Chapter 8, the tokamak is a safe and reliable source of fusion energy. The underground portion of the tokamak, which is built at the same time as the surface portion, is part of the containment vessel. You have the option of bringing down the tokamak from the starship, or building new ones after you have developed the technology and research with local resources to make it work.

Input

Number of versions of this tile	2
Number of turns required to build this tile:	2 (if from starship) 9 (built from scratch)
Energy required to build this tile:	1
Energy required to operate this tile:	0
Population required to build this tile:	2
Population required to operate this tile:	1
Resources required to build this tile:	From starship: LSA, LSB, & LSC From scratch: LSA, LSB, & LSC PMA, PMB, PMC, PMD PRMA, PRMB FEA, FEB, FEC MA, MB, MC
Resources required to operate this tile:	FEA, FEB, FEC

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	Power
Special effects:	0
Percentage Chance of Breakdown:	5 (if from starship) 30 (built from scratch)
Recycling value:	10

Tube

The Tubes are the lifelines for most of your colony structures. Tubes provide the connections between your CHAP Facilities, which create air and life support for your buildings; the SPEW Facilities, which recycle your colony's wastes; and your power facilities. At the same time, they provide a shielded method for your colonists to travel from building to building.

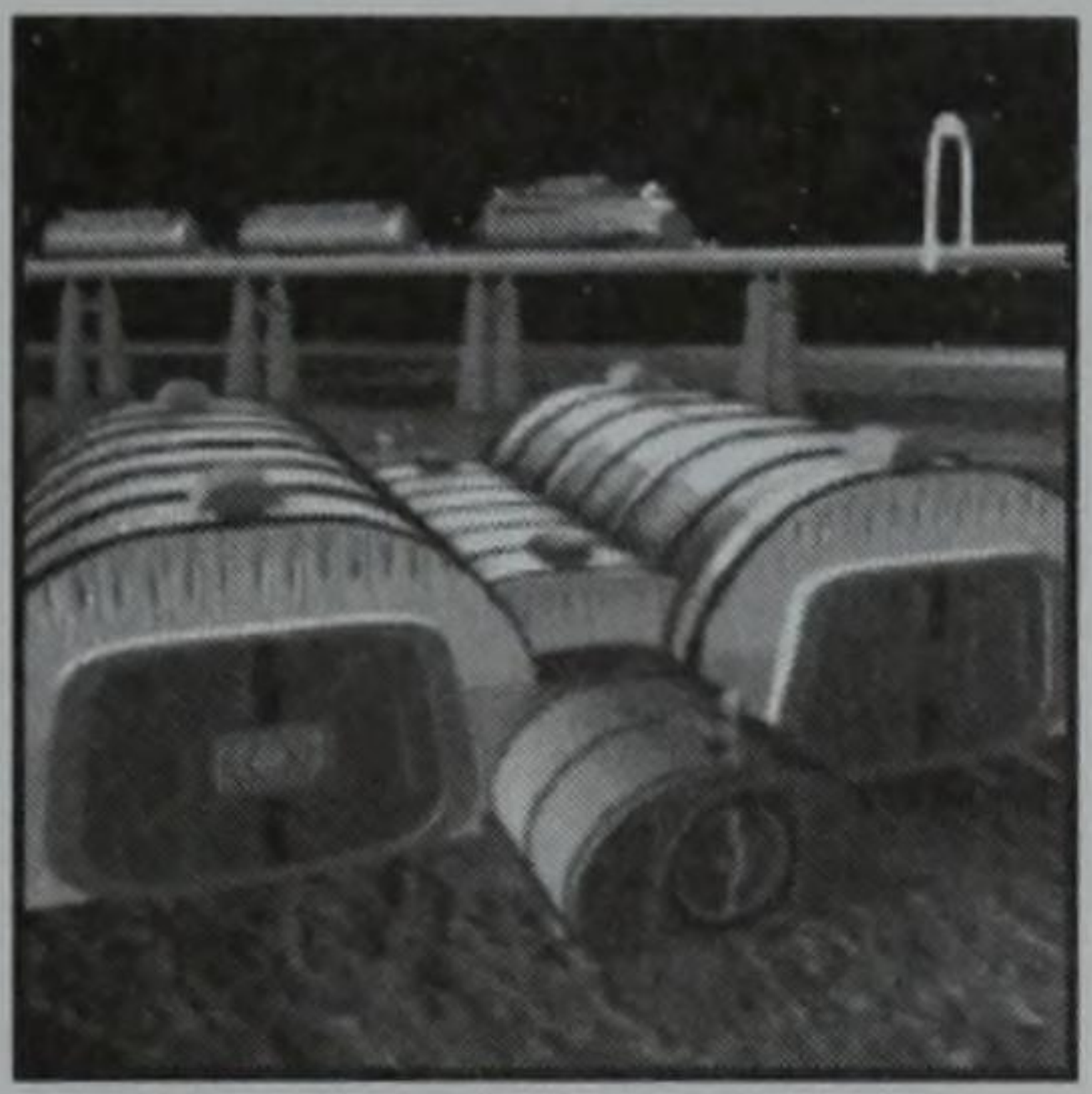
Input

Number of versions of this tile:	3 different directions
Number of turns required to build this tile:	1
Energy required to build this tile:	1
Energy required to operate this tile:	0
Population required to build this tile:	1
Population required to operate this tile:	0
Resources required to build this tile:	LSA, LSB, LSC PMA
Resources required to operate this tile:	0

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	0
Recycling value:	1

Warehouse



The Warehouse provides additional space, beyond what's available at your factories, for the storage of medicine (1 mass unit), fuel cells (2 mass units), luxury items (3 mass units), road materials (3 mass units), robots (3 mass units without a fuel cell, 5 mass units with a fuel cell), and trucks (6 mass units). Each Warehouse can hold 100 mass units of storage.

Input	
Number of versions of this tile:	2
Number of turns required to build this tile:	2
Energy required to build this tile:	2
Energy required to operate this tile:	1
Population required to build this tile:	2
Population required to operate this tile:	1
Resources required to build this tile:	LSA, LSB, LSC PMA, PMD MA
Resources required to operate this tile:	LSA

Output	
Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	5
Recycling value:	3

Underground Structures

Administration Building

The underground Administration building provides a management connection so that you can form research parks and industrial parks. Light Industry tiles immediately adjacent to an Administration building will improve their rate of production by 1 point per turn. Laboratories immediately adjacent to an Administration building will improve their rate of research progress by 1 point per turn.

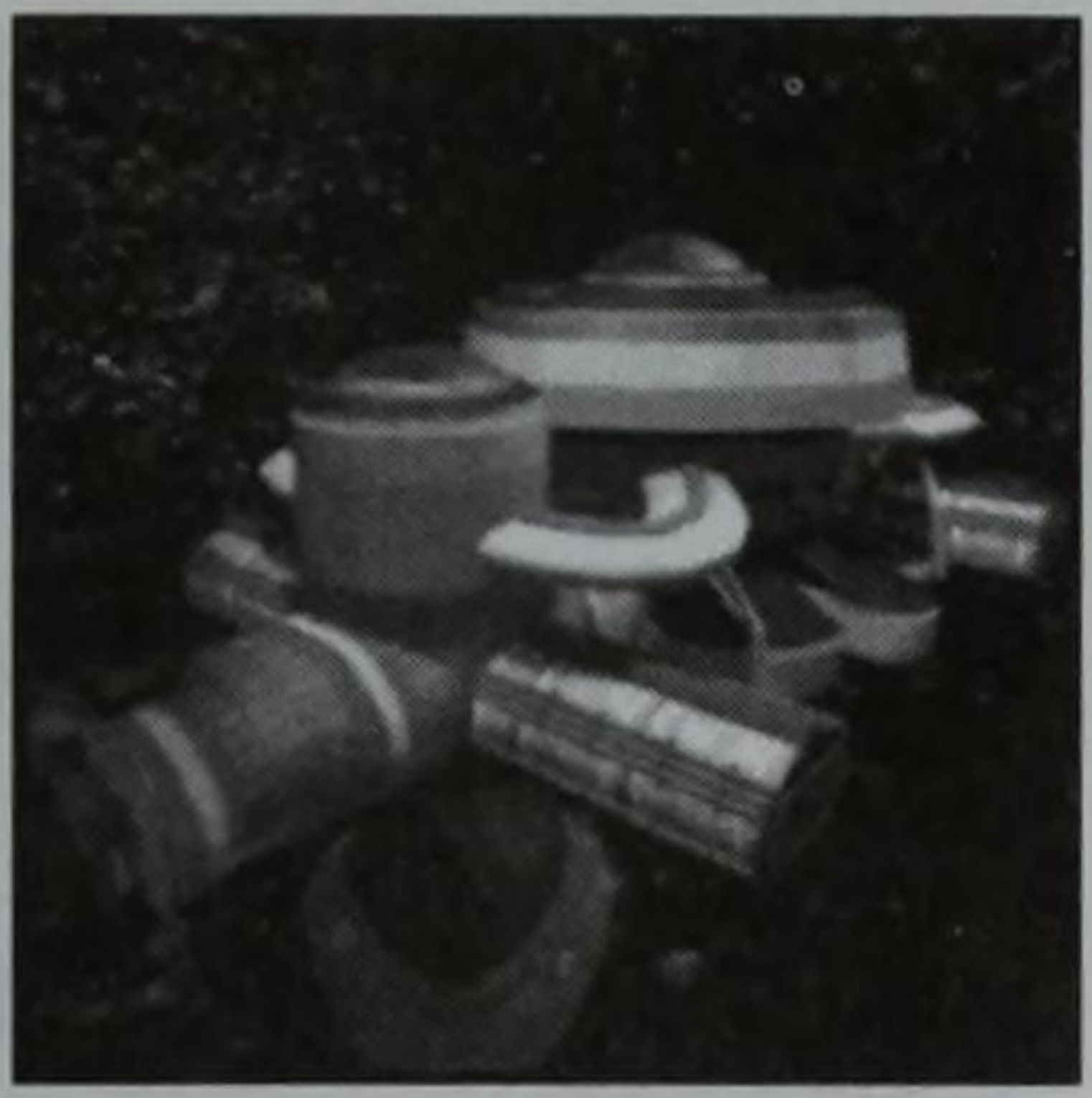
Input

Number of versions of this tile:	2
Number of turns required to build this tile:	3
Energy required to build this tile:	2
Energy required to operate this tile:	1
Population required to build this tile:	2
Population required to operate this tile:	1
Resources required to build this tile:	LSA PMA, PMC PRMA MA, MB
Resources required to operate this tile:	0

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	+1 SWG
Production bonus:	+1 on adjacent product mfg.
Research bonus:	-1 on research time required
Percentage Chance of Breakdown:	10
Recycling value:	2

Commercial



The Commercial structure is the general store for the colonists. After they have been produced by the underground Light Industry, luxury items are distributed to the colonists through the Commercial tiles. If no Commercial tiles exist in a colony, luxury items will just pile up in storage unless they are smuggled out the back door by the colonists and distributed to the "employees" of the Red Light Districts.

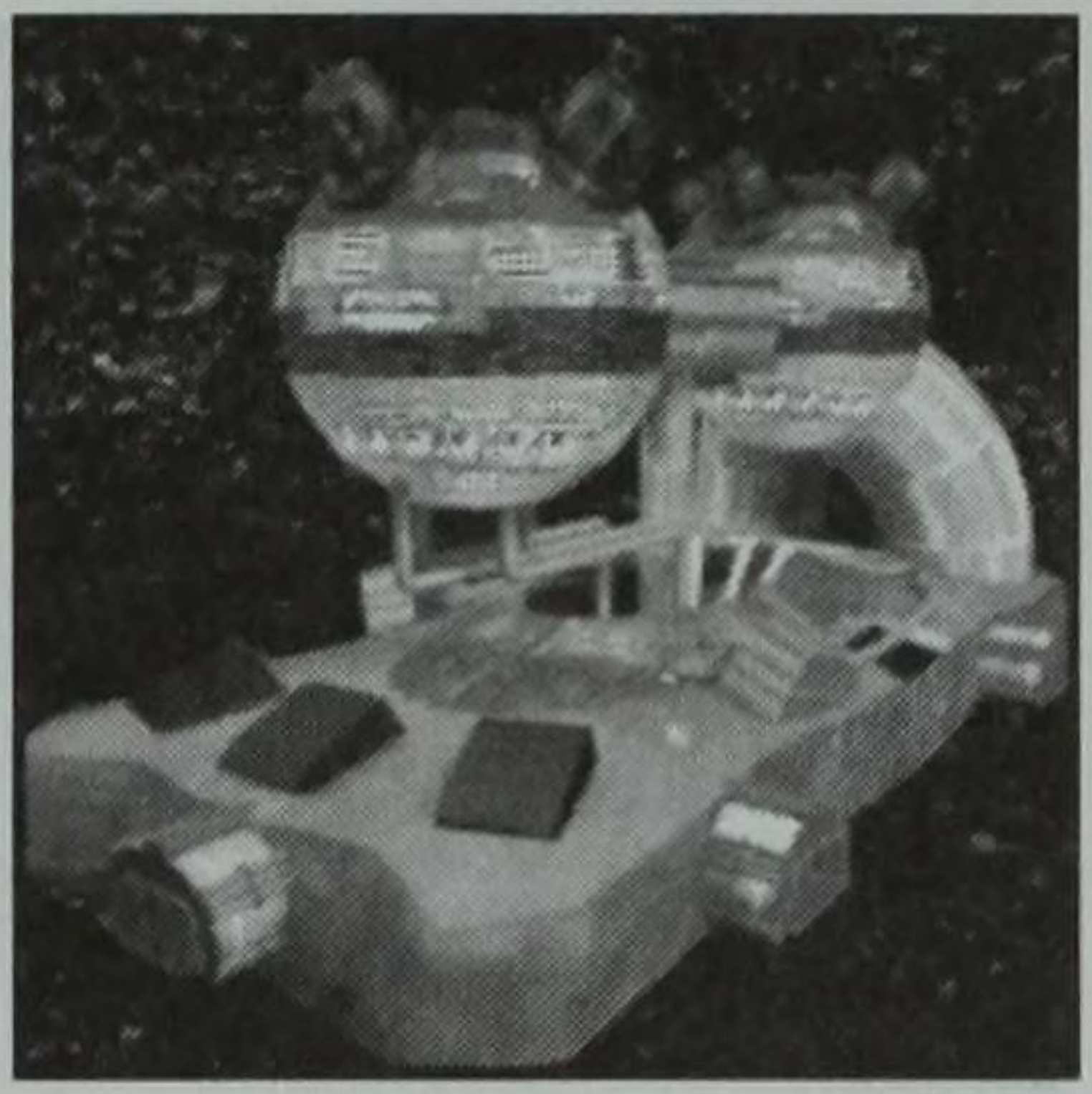
Input

Number of versions of this tile:	3
Number of turns required to build this tile:	3
Energy required to build this tile:	4
Energy required to operate this tile:	3
Population required to build this tile:	2
Population required to operate this tile:	2
Resources required to build this tile:	LSA PMA, PMB, PMD MA
Resources required to operate this tile:	LSA

Output

Morale effect:	+1 per turn while luxury supply lasts
Luxury effect:	-1 per turn until no luxury supply
Manufactured Production effect:	0
Special effects:	+1 RCY
Percentage Chance of Breakdown:	10
Recycling value:	2

Geothermal Power Plant



The Geothermal Power Plant is a clean source of energy, assuming you're on the right type of planet and you're lucky enough to find a steam vent (fumarole) underground. The planets in the original Outpost game are not volcanically active on the surface, so steam vents can be located only by subterranean digging. The Geothermal facility is described in more detail in Chapter 8.

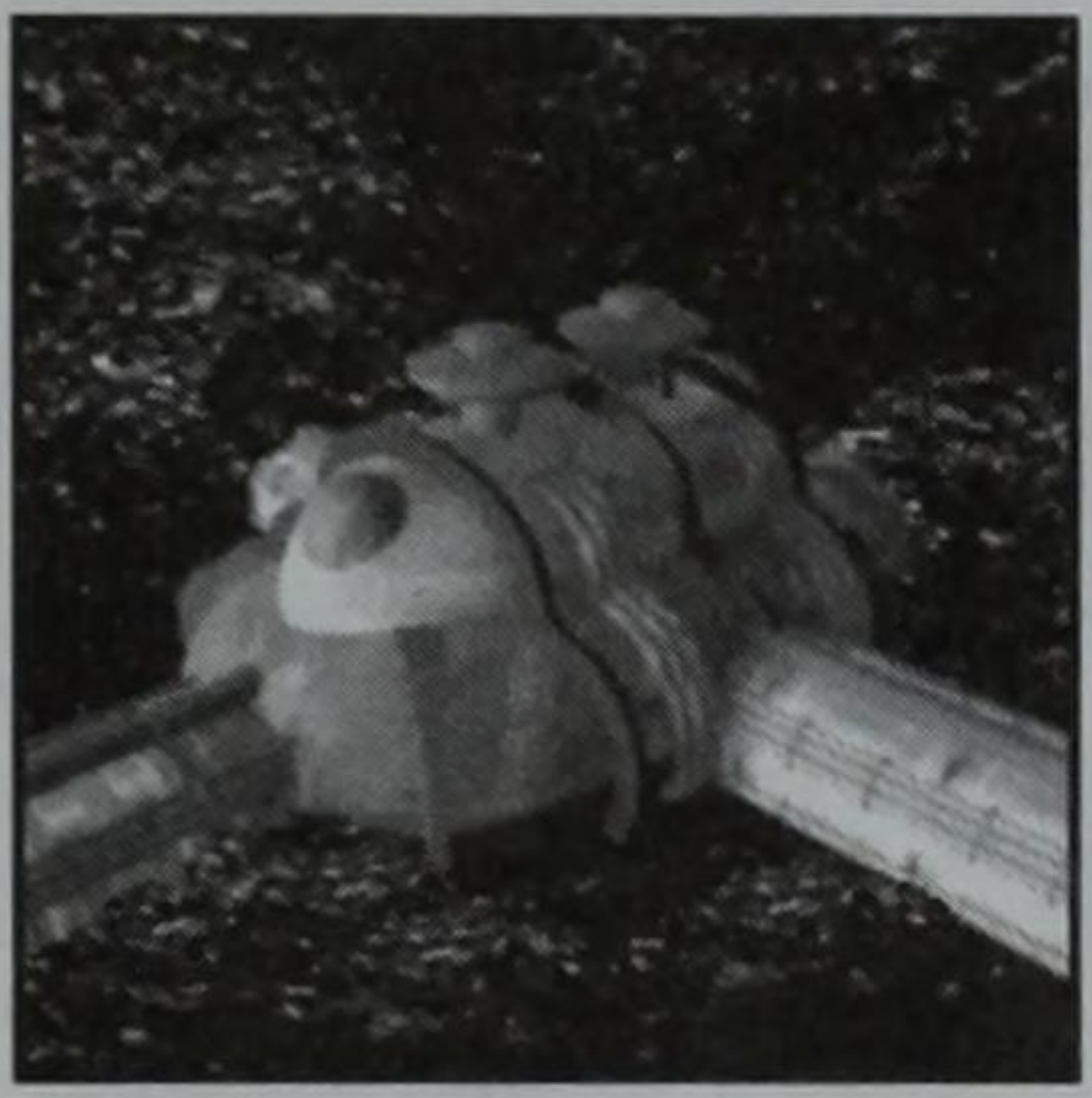
Input

Number of versions of this tile:	1
Number of turns required to build this tile:	9
Energy required to build this tile:	3
Energy required to operate this tile:	0
Population required to build this tile:	2
Population required to operate this tile:	1
Resources required to build this tile:	LSA PMA, PMB, PMC, PMD MA, MB, MC
Resources required to operate this tile:	Geothermal source

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	Power
Special effects:	0
Percentage Chance of Breakdown:	20
Recycling value:	10

Laboratory



The underground Laboratory is where most scientific research is performed. The surface laboratories are only for the "dangerous" experiments, such as genetic engineering and nanotechnology. The Laboratory also has a beneficial effect on the Educational level of the colonists, but not as much as a University. The Laboratory also gives you direct access to the Research Tree, described in Chapter 14, so that you can determine the nature of the research being performed.

Input

Number of versions of this tile:	3
Number of turns required to build this tile:	4
Energy required to build this tile:	4
Energy required to operate this tile:	3
Population required to build this tile:	3
Population required to operate this tile:	2
Resources required to build this tile:	LSA PMA, PMB, PMC, PMD PRMA, PRMB MA, MB, MC
Resources required to operate this tile:	PRMA, PRMB MA, MB, MC

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	Research
Special effects:	+1 SWG
Educational level	+1 per turn
Percentage Chance of Breakdown:	20
Recycling value:	2

Light Industry

The Light Industry tile is an underground manufacturing facility that does not produce toxic by-products such as those made by the surface factories. Light Industry can produce luxury items, clothing, or medicine. Recyclables (RCY) from the various manufacturing processes are automatically sent to the SPEW recycling facility on a regular basis.

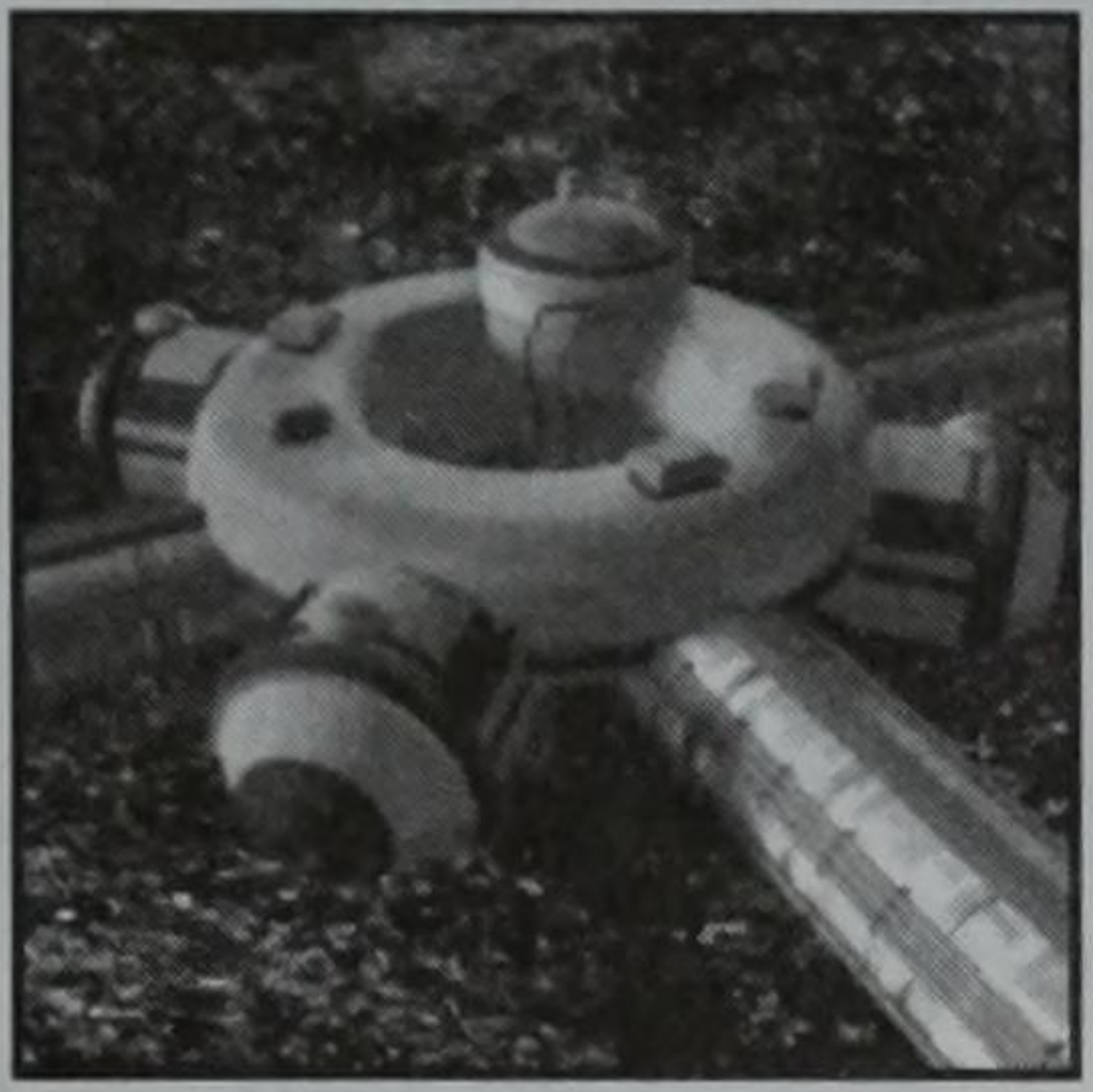
Input

Number of versions of this tile:	2
Number of turns required to build this tile:	4
Energy required to build this tile:	4
Energy required to operate this tile:	3
Population required to build this tile:	3
Population required to operate this tile:	2
Resources required to build this tile:	LSA PMA PRMA, PRMB MA, MB, MC
Resources required to operate this tile:	PMA MA, MB, MC

Output

Morale effect:	0
Luxury effect:	+1 per turn if making luxury items
Manufactured Production effect:	Luxury, clothing, medicine
Special effects:	+1 RCY
Percentage Chance of Breakdown:	20
Recycling value:	4

Medical Facility



The Medical Facility reduces the damage done to colonists affected by disasters, and improves the longevity of babies and the adult population. Because there are numerous potential medical effects that result from living on a hostile planet, the Medical Facility generally improves the health of the population by helping people adapt to the environment.

Input

Number of versions of this tile:	2
Number of turns required to build this tile:	4
Energy required to build this tile:	3
Energy required to operate this tile:	2
Population required to build this tile:	2
Population required to operate this tile:	2
Resources required to build this tile:	LSA PMA, PMB, PMC MA, MB, MC PRMB
Resources required to operate this tile:	LSA, LSB PRMB

Output

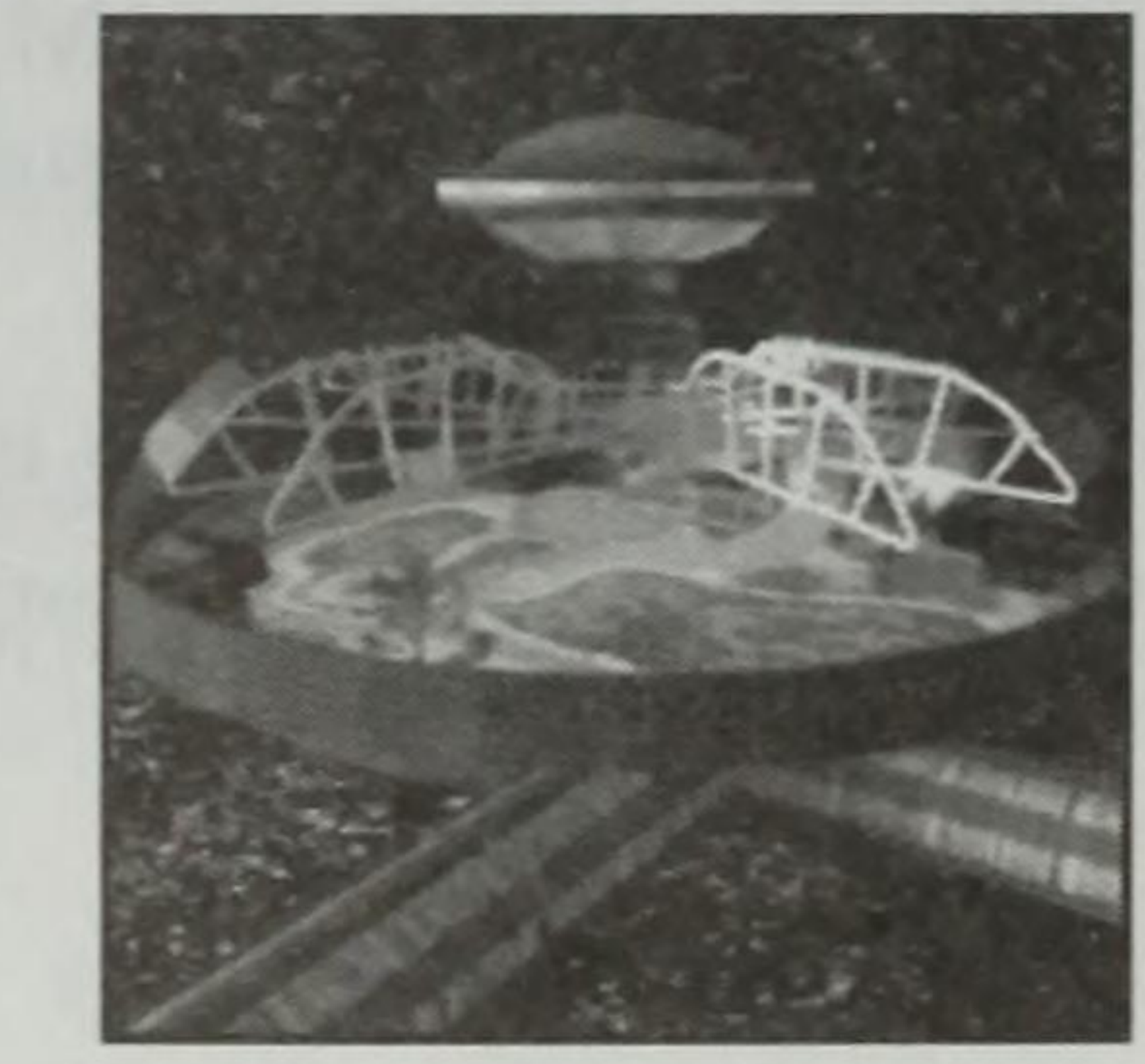
Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	+1 SWG
Health	Life extension
Percentage Chance of Breakdown:	20
Recycling value:	4

Mine Shaft (Active)

The Mine Shaft is built by the robominer, so this is not a structure you can build directly by placing it on the underground portion of the map. It exists to mark the location of the mine, which you should not interfere with unless you want a nasty surprise.

Input	
Number of versions of this tile:	2
Number of turns required to build this tile:	Varies by terrain
Energy required to build this tile:	0
Energy required to operate this tile:	0
Population required to build this tile:	0
Population required to operate this tile:	0
Resources required to build this tile:	Robominer
Resources required to operate this tile:	0
Output	
Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	Mined ore
Special effects:	0
Percentage Chance of Breakdown:	0
Recycling value:	1

Park/Reservoir



When parents are living on a hostile planet, they can't just tell their kids to go play outside. The main function of the Park is to provide a safe environment for children, and adults, in which to play. This results in improved morale.

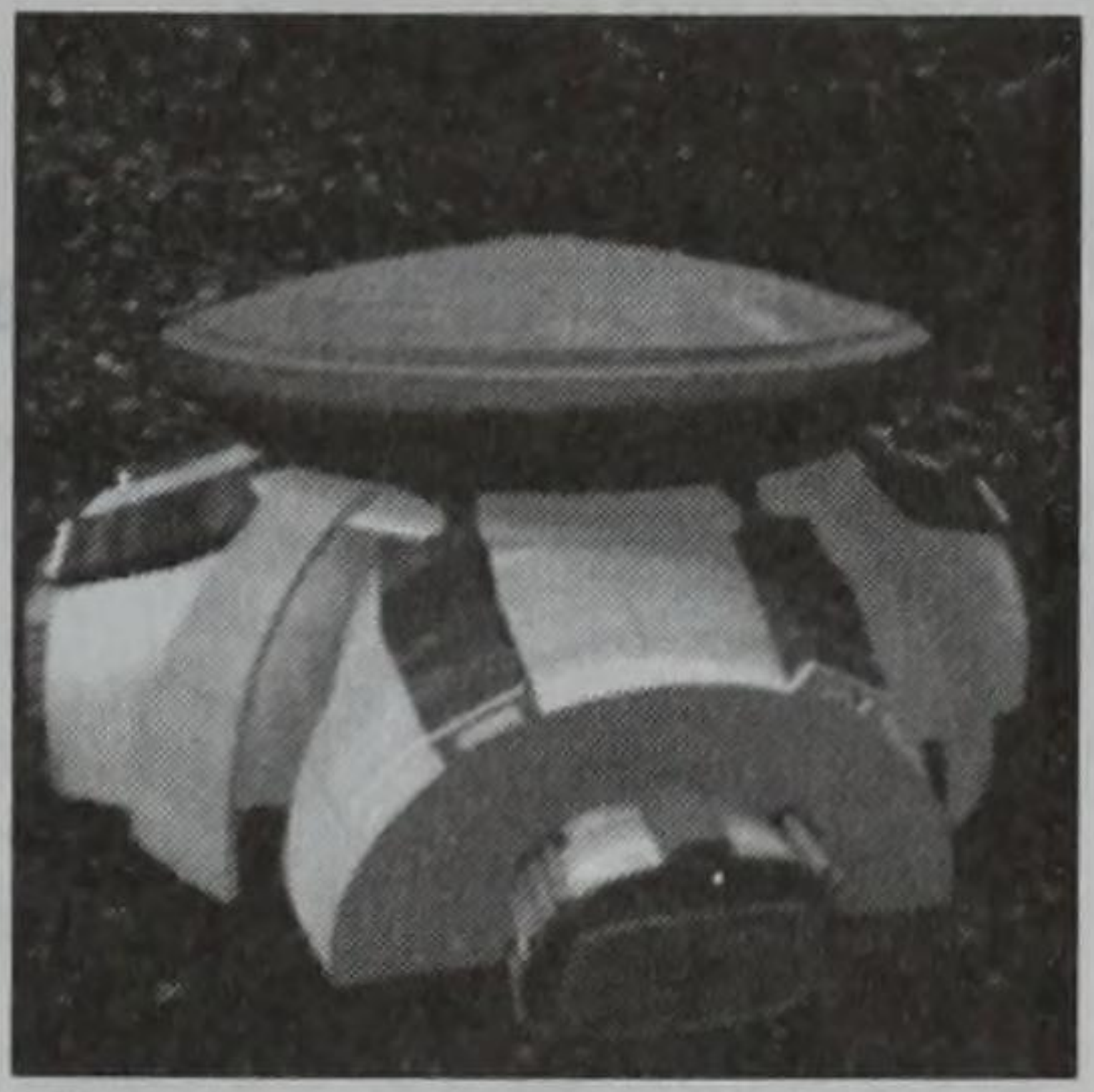
Input

Number of versions of this tile: 1
Number of turns required to build this tile: 3
Energy required to build this tile: 2
Energy required to operate this tile: 1
Population required to build this tile: 1
Population required to operate this tile: 0
Resources required to build this tile: LSA
PMA
MA, MB, MC
Resources required to operate this tile: 0

Output

Morale effect: +1 per turn
Luxury effect: 0
Manufactured Production effect: 0
Special effects: 0
Percentage Chance of Breakdown: 10
Recycling value: 1

Recreational Facility



The primary function of the Recreational Facility is to provide the colonists with some entertainment to improve their morale.

Input

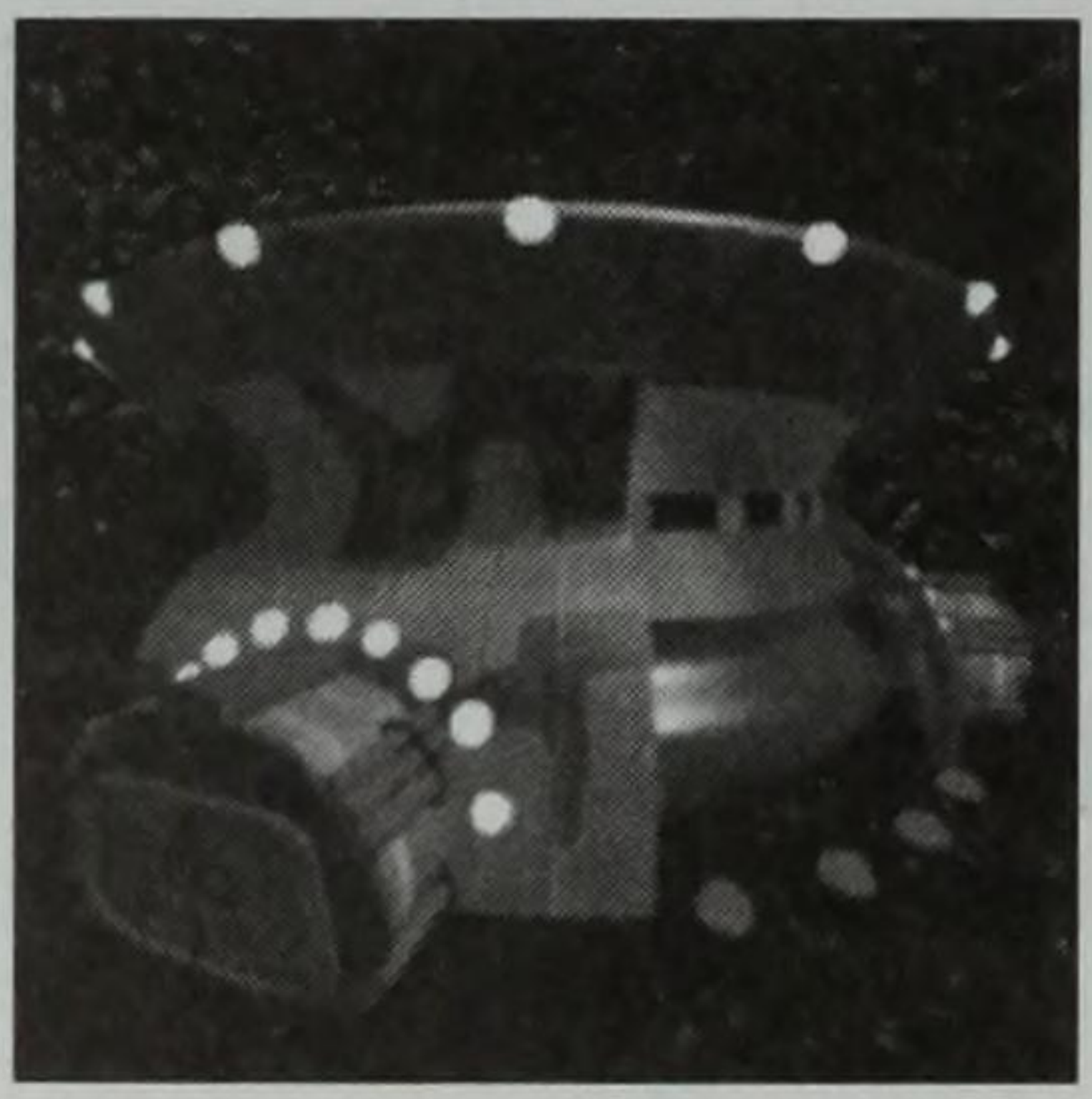
Number of versions of this tile: 2
Number of turns required to build this tile: 4
Energy required to build this tile: 2
Energy required to operate this tile: 1
Population required to build this tile: 2

Population required to operate this tile:	1
Resources required to build this tile:	LSA PMA, PMC, PMD PRMA MA, MB, MC
Resources required to operate this tile:	LSA

Output

Morale effect:	+1 per turn
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	+1 SWG
Percentage Chance of Breakdown:	20
Recycling value:	2

Red Light District



The Red Light District (RLD) has its advantages and disadvantages. It's an unusual structure, because you can place it on the map yourself, but it can also be spontaneously generated due to a high Crime level. Although the RLD improves morale and the birth rate, it also draws 2 units of luxury items per turn, drawn directly from storage whether or not a Commerical structure exists, for maintaining operation. If the Crime level remains high, more and more of your Residential units will turn into RLDs. The only way to control the spread of RLDs is to lower your luxury production or lower your Crime level by adding Police Stations to your colony near the RLDs. Of course, if you're using the "Criminal Empire Strategy," detailed in Chapter 20, you can ignore the Police Stations and just let the RLDs take over the Residential units (forcing you to build more Residential units).

Input

Number of versions of this tile:	1
Number of turns required to build this tile:	4
Energy required to build this tile:	3
Energy required to operate this tile:	2
Population required to build this tile:	2
Population required to operate this tile:	2
Resources required to build this tile:	LSA PMA, PMD PRMA
Resources required to operate this tile:	LSA

Output

Morale effect:	+2 per turn
Luxury effect:	-2 (draws Luxury to maintain)
Manufactured Production effect:	0
Special effects:	+1 SWG
Crime level:	+1 per turn
Birth rate:	+1 baby per turn
Percentage Chance of Breakdown:	0
Recycling value:	0

Residential Unit

Residential units are necessary to house your population in comfort as soon as possible. During the arrival phase, your colonists live in the crowded conditions of the Command tile that was build by your Seed Factory, but this is only an interim measure until the Residential units are built underground. Because it's also dangerous living on the surface, morale will start dropping soon after you land. It's best if you have fewer than 25 people living in each Residential unit, as this will improve their morale. The legal occupancy limit is 25, so if you cram more than 25 people into a Residential unit, the Crime level will start rising and morale will start dropping.

Input

Number of versions of this tile:	3
Number of turns required to build this tile:	3
Energy required to build this tile:	3
Energy required to operate this tile:	2
Population required to build this tile:	2
Population required to operate this tile:	1
Resources required to build this tile:	LSA PMA, PMB MA, MC
Resources required to operate this tile:	0

Output

Morale effect:	(See Special effects)
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	+1 SWG
Population Density:	-25 = 0 Crime and +1 Morale 25 = 0 effect on Crime and Morale 25+ = +1 Crime and -1 Morale
Percentage Chance of Breakdown:	10
Recycling value:	2

Spaceport Warehouse

The Spaceport Warehouse is generated underground when you build a Spaceport on the surface. This is not a structure you can build independently of the Spaceport, but it does represent the storage capability of the Spaceport, which is 100 mass units (described in Chapter 10). You can store satellites or probes here

(6 mass units each), or heavy lifters (10 mass units each), or Low-orbit freighters (10 mass units each), or asteroid miners (9 mass units each).

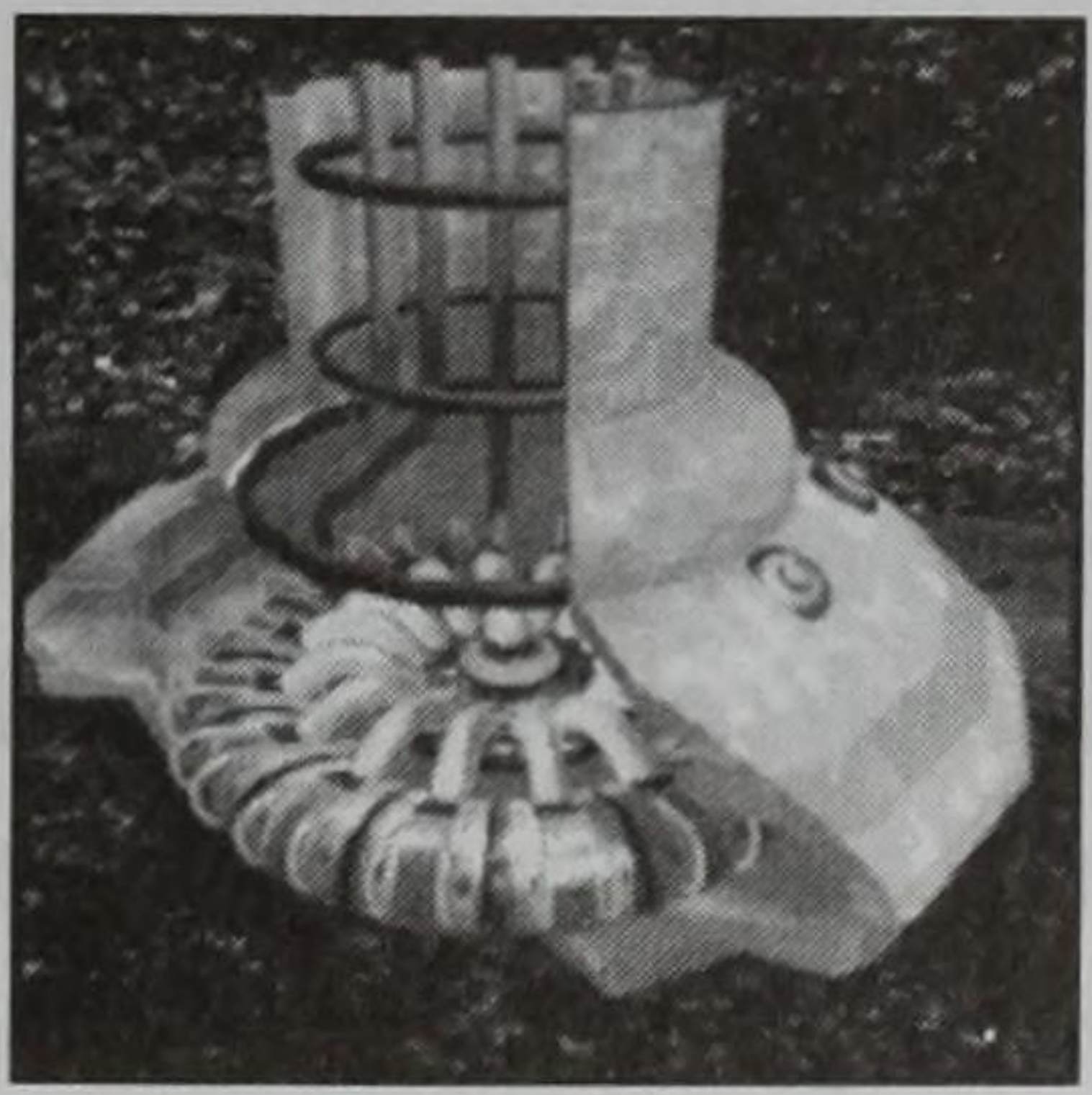
Input

Number of versions of this tile:	1
Number of turns required to build this tile:	2
Energy required to build this tile:	2
Energy required to operate this tile:	1
Population required to build this tile:	2
Population required to operate this tile:	1
Resources required to build this tile:	LSA PMA, PMD MA
Resources required to operate this tile:	LSA

Output

Morale effect:	0
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	5
Recycling value:	3

Tokamak Containment Vessel



The Tokamak Containment Vessel is the lower portion of the Tokamak Fusion Reactor built directly above it on the surface. This Containment vessel is generated when you build the surface structure, so it's not an option for you to build. However, you don't want to build new structures adjacent to a Containment vessel because it makes those colonists nervous.

Input

Number of versions of this tile:	2
Number of turns required to build this tile:	Varies by terrain
Energy required to build this tile:	0
Energy required to operate this tile:	0
Population required to build this tile:	0
Population required to operate this tile:	0
Resources required to build this tile:	0
Resources required to operate this tile:	0

Output

Morale effect:	-1 if other buildings adjacent
Luxury effect:	0
Manufactured Production effect:	0
Special effects:	0
Percentage Chance of Breakdown:	0
Recycling value:	1

University

The University maintains and improves the Educational level of your population, which also has a beneficial effect on morale. After 100 turns, the crowding and the heavy use of aging University equipment stops increasing the Educational level at that University, but the improved effect on morale will continue. Because the maximum Educational level is 100, you may hit the limit sooner than 100 turns, but the level does degrade over time due to new children entering the educational system.

Input

Number of versions of this tile: 3
Number of turns required to build this tile: 4
Energy required to build this tile: 3
Energy required to operate this tile: 2
Population required to build this tile: 2
Population required to operate this tile: 2
Resources required to build this tile: LSA
PMA, PMB, PMC
MA, MB, MC
PRMB
Resources required to operate this tile: PRMB

Output

Morale effect: +1 per turn
Luxury effect: 0
Manufactured Production effect: 0
Special effects: +1 SWG
Educational Level: +2 per turn (to maximum 100)
Percentage Chance of Breakdown: 20
Recycling value: 2

Building Groups

These structures are grouped according to the number of turns (zero to nine) required to build or prepare them before they will begin operation.

Zero Turns:
Abandoned Mine
Undeveloped Terrain

One Turn:
Administration/Trade Mission
Tube
Trade Mission

Two Turns:
Communications Tower
Road
Seed Factory
Tokamak Fusion Reactor (from starship)
Warehouse

Three Turns:
Administration
Commercial
Park/Reservoir
Police Station (underground)
Residential unit
Robot Command

Four Turns:
Laboratory (underground)
Light Industry
Police Station (surface)
Recreational
Red Light District
Solar Powersat Receiver Array
University

Five Turns:
Agricultural Dome
DIRT Facility
Hot Laboratory
Nanotechnology Facility

Six Turns:
CHAP Facility
Factory (surface)

Seven Turns:
Monorail (per segment)
Smelter/Ore Processing Facility
Spaceport

Eight Turns:
SPEW Facility

Nine Turns:
Mass Driver (per segment)
Terraforming Facility
Tokamak Fusion Reactor (built from scratch)

Energy Classes

With regard to energy requirements, the structures are grouped according to their similarities in power consumption. These six energy classes apply once the structure is built; during construction, in most cases, the extra power requirement will be indicated by adding one level to that structure's normal Energy Class.

CLASS 0:
Abandoned Mine
Administration/Trade Mission
Command
Geothermal Power Plant
Road
Seed Factory
Tokamak Fusion Reactor
Trade Mission
Tube

CLASS 1:
Administration
Park/Reservoir
Recreational
Solar Powersat Receiver Array
Warehouse

CLASS 2:
Agricultural Dome
Red Light District
Residential unit
University

CLASS 3:
Commercial
Light Industry
Nanotechnology Facility
Police Station
Robot Command
SPEW
Laboratory (underground)

CLASS 4:
Communications Tower
DIRT
Monorail (per segment)
Hot Laboratory (surface)

CLASS 5:
CHAP Facility
Factory (surface)
Mass Driver
Mine (active)
Smelter/Ore Processing Facility
Spaceport
Terraforming Facility

The Architect of the Future

This chapter has given you simple descriptions and detailed requirements for all the colony structures. It's up to you to absorb this information so you can develop an educated strategy and tactical plan. Chapter 20 will discuss some of the possible strategies you can use for success with your O*utpost*. Details on the functioning of individual colony structures are distributed throughout this book.

In the next chapter, we'll look at factory production and how you can use it to suit your needs for global conquest.

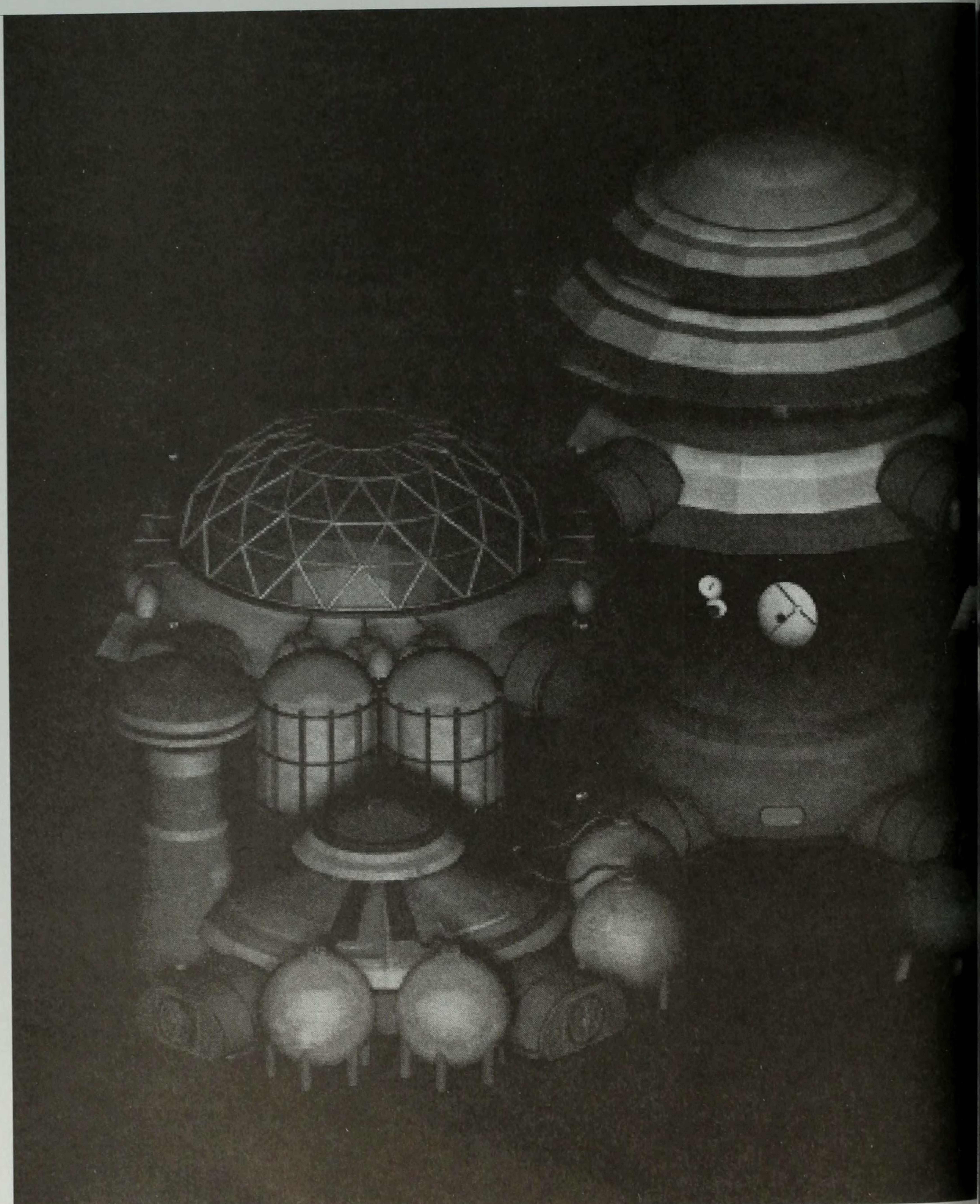
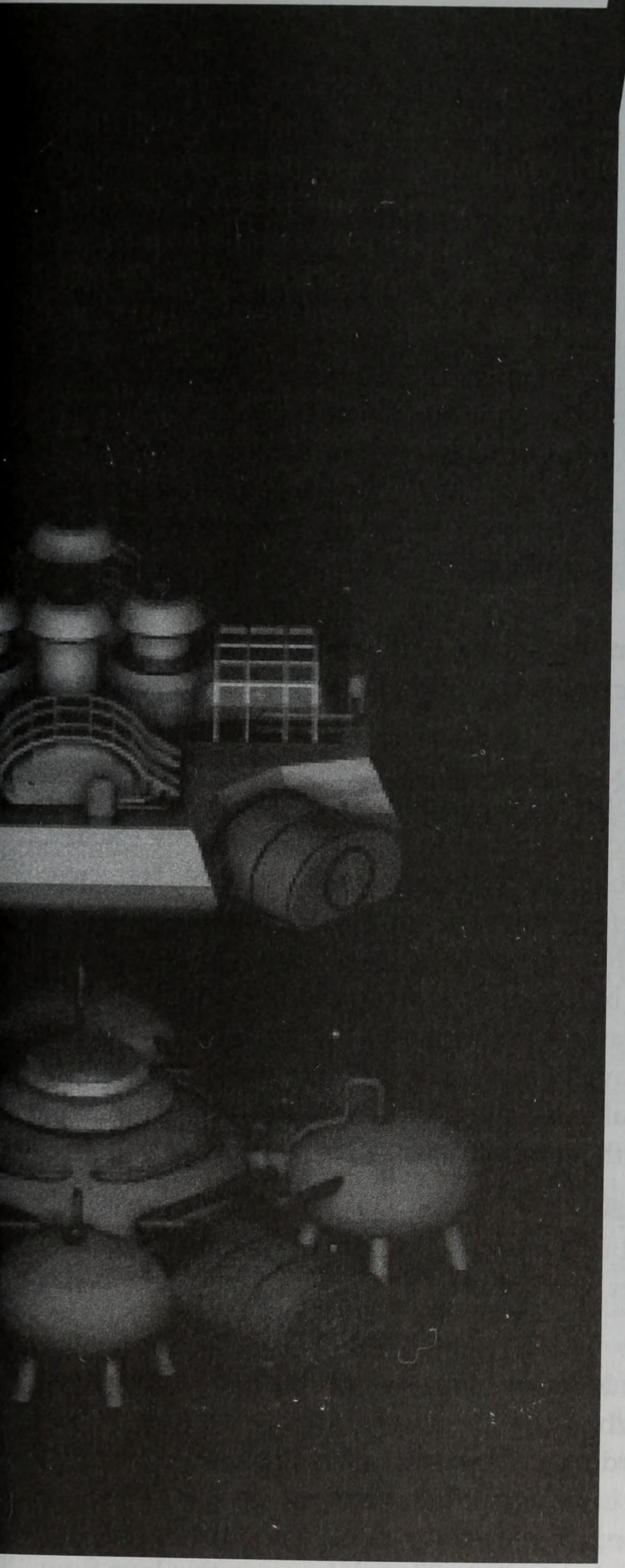


Figure 10-1 Surface colony structures



10

Factories

Just as there must be balance in what a community produces, so there must also be balance in what the community consumes.

John Kenneth Galbraith,
The Affluent Society (1958)

So, you want to be a captain of industry? Now you have your chance. *Outpost* gives you factories that operate on the surface of a planet, and light industry that operates underground. The light industry is clean and nonpolluting, so it's suited to the contained environment underground where your population spends most of its time. Surface factories, which require much more in terms of raw resources and energy, are heavily shielded against cosmic radiation and are placed on the surface so that they won't contaminate the underground environment.

With so many shielded facilities on the surface for your population to work in, you must remain alert to events that can endanger those lives, such as incoming meteorites or the radiation from solar flares. When these alerts occur, you must warn your workers and evacuate them underground for their safety. Believe me, they'll appreciate your management skills much more if they're alive to appreciate them.

This chapter uncovers the secrets of successful factory production and personnel management within the unique confines of the *Outpost* world.

Should I Make Fuel Cells or Bowling Shoes?

When you have completed construction of a factory on the surface of your planet, such as the one in Figure 10-2, you are given a choice as to what will be produced by that factory. These factories, designed on Earth before you left, are not as specialized as the traditional factory. They are built with a moderate amount of automation that can be adapted to multiple uses by the small human staff that operates and supervises that facility. By keeping a careful eye on your available resources and types of production, you can maintain a balanced program of factory production and plan for the future with warehouse storage.

Surface Factories

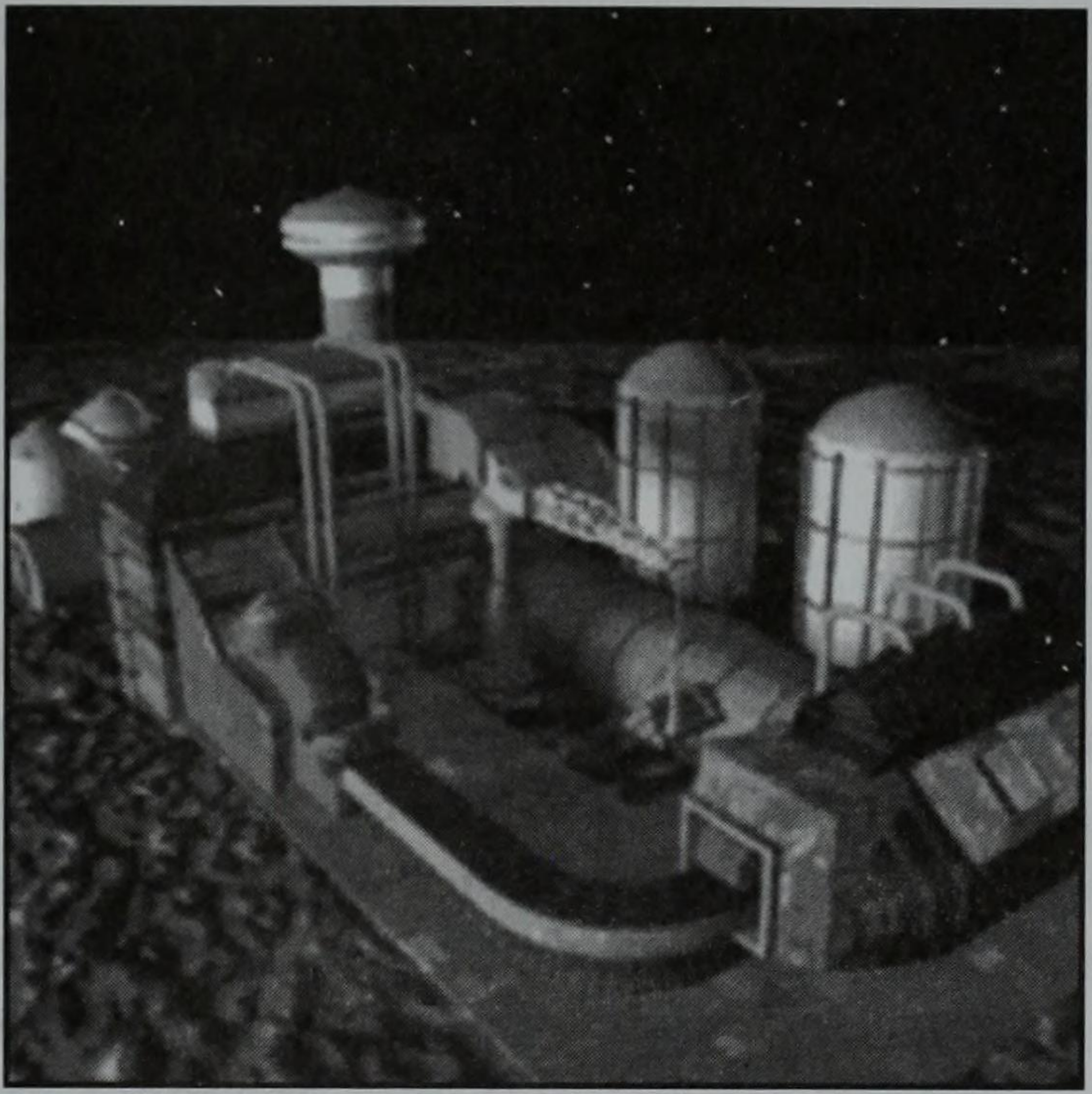
A surface factory can build four basic products: road material, fuel cells, robot spare parts, and robots.

Road Material

Road material is a combination of dense and sturdy materials used to form a durable roadbed on a bulldozed surface. The mix of these materials varies according to the hostility of the planet you intend to build the road on, but the flexibility and toughness of the finished road will enable it to last a long time even in the harshest of climates. Of course, if the road gets covered over with a lava flow,

Figure 10-2

Factory



it will need to be replaced, but that's how the road crews stay employed, right? You've seen them standing by the side of the road with their trucks, blocking traffic as they take yet another of their 23 daily breaks. They obviously don't have enough to do, so the more road material you produce, the more roads you can build to keep these unfortunate workers busy.

The only advantage to the road crew of six people is that they will get right to work when you assign them to a job by placing a road on the map. Road material is produced at the rate of one unit per turn by the factory. A road takes two turns to complete, which allows the union road crew time to take all their breaks.

Fuel Cells

Fuel cells, described in Chapter 8, are fancy batteries containing oxygen and hydrogen gases that are electrochemically combined by phosphoric acid within the fuel cell to produce energy.

Fuel cells are produced at the rate of one every 10 turns. One fuel cell is required to power each new robot. Every fuel cell that has been used in a robot for 200 turns must be replaced. Cell replacement is one of the functions served by repairbots, who can go straight to the site of the dead robot and give it new life, as long as a fresh fuel cell is available from storage. Each fuel cell takes 2 mass units of storage when it's not attached to a robot, so you can store 50 of them in a warehouse.

Robot Spare Parts

As long as robot spare parts are available from storage, a repairbot can serve its main function of repairing broken robots. Because of the variety and complex nature of the spare parts that need to be replaced on the typical broken robot, spare parts are produced at the rate of one every 10 turns.

Robots

The Seed Factory is able to serve your early needs as a robot factory, but a regular surface factory, which is also more efficient, can build the full range of robots, including the new types you're able to develop through scientific research. You can choose to produce the robodozer, robominer, robodigger, roboexplorer, repairbot, airbot, microbot, lawbot, humanoid worker, or the semiautomated truck, which is supervised by a human through telepresence.

A factory can produce only one robot type at a time, but it can build them at the rate of one every five turns. However, the active robot population is limited by fuel cell production and robot command capability, in addition to the need for the basic resources to produce them. Both of these limitations are discussed in Chapter 11.

One of the Warehouse options is for the storage of robots. Storage at a surface factory is limited to 10 robots, after which production shuts down until the robots are deployed or stored in a warehouse. Warehouse storage can accommodate 100 mass units, and each robot has a value of 5 mass units with a fuel cell, so a single warehouse can store up to 20 robots with fuel cells, or 33 robots without fuel cells.

Underground Factories

The light industry that operates underground is oriented toward three categories of production: medicine, clothing, and luxury items.

Medicine

Pharmaceuticals that have been discovered through research can be produced through the underground factories. Medicine is produced at the rate of 1 unit per turn. When a medical emergency, such as an alien virus, strikes your colony, stored medicine is automatically used to fight the plague. If there is no medicine in storage, your colonists are out of luck. Medicine has a storage value of 1 mass unit, which means that 100 units of medicine can be placed in a warehouse.

Clothing

Your colonists tend to prefer simple, durable clothing, so once it's produced, at the rate of 1 unit per turn, it tends to last a long time. Clothing is distributed through the underground Commercial structure. One unit of clothing takes up 3 mass units of storage, so 33 units of clothing can be stored in a warehouse.

Luxury Items

Desperate for entertainment, your colonists are always happy to get luxury items. Luxury items are produced at the rate of one per turn per factory, but they will not be available to the population unless a Commercial structure exists in the colony to distribute the items. Luxury items provide your primary means of manipulating the morale of your colonists, and are therefore very important for maintaining high production levels in the factories. These are the luxury items you can choose to produce: whoopee cushions, bowling shoes, golf balls, salad spurters, fuzzy dice, eight-track tapes, croquet mallets, *Neuromancer* computer games, Laura Bow II hint books, wax lips, beachballs, squirting flowers, or chia figurines.

Commercial structures draw from the supply of luxuries at a rate of one per turn as long as there are luxury units available. Each turn where luxury items are being distributed increases the Morale level of the population by 1 unit.

Special Factories

Outpost allows for four categories of "special" factories. Each of these surface facilities is dedicated to producing one type of product. Most of these are available soon after the game starts, but the terraforming facility (a fifth category) is available only after suitable research has been completed.

Agricultural Dome

The Agricultural Dome, shown in Figure 10-3, produces food units. Food production at the dome is directly affected by the hostility of the planet and its distance from the local star, which determines how much solar energy is received at the planet's surface. Each dome produces 10 units of food per turn, assuming the dome receives enough resources each turn. The storage available at a dome is 1,000 mass units, after which dome food production is shut down until the stored food is consumed. No other storage for food is available. One food unit feeds 10 humans per turn.

Figure 10-3

Agricultural dome

Any research resulting in a new source of food produces a bonus of 10 food units per turn per completed new food source.

Smelter

The smelter processes ores from the mines into pure, useful resources that can be used by the colony. Although there is more detail on the smelter and the mining process in Chapter 7, the process is outlined here.

When ores are mined, they show up on your mining reports as Metal Ores A, Metal Ores B, Metal Ores C, and Metal Ores D. A mine can also produce Minerals A, Minerals B, and Minerals C; as well as Fusion Elements A, Fusion Elements B, and Fusion Elements C. The two forms of Precious Metals (A and B) are extracted as components of the Minerals, so you won't really know how many Precious Metals you have until the Minerals have been processed through the smelter.

After the mined ores have been delivered to the smelter, they are converted into Processed Metals A, Processed Metals B, Processed Metals C, and Processed Metals D.

Because they lose their unstable components during processing, ores produce only half their weight in processed metals. Minerals lose nothing, but require purification in the smelter before use, so 2 units of Minerals will produce 2 units of processed Minerals.

Minerals sometimes contain Precious Metals in small amounts which are extracted through the smelter processing.

Fusion Elements are processed at a 1:1 ratio. By passing through the smelter, the impurities in the Fusion Elements are removed to produce reactor-grade nuclear material. A tokamak reactor requires substantial quantities of all three elements to generate power.

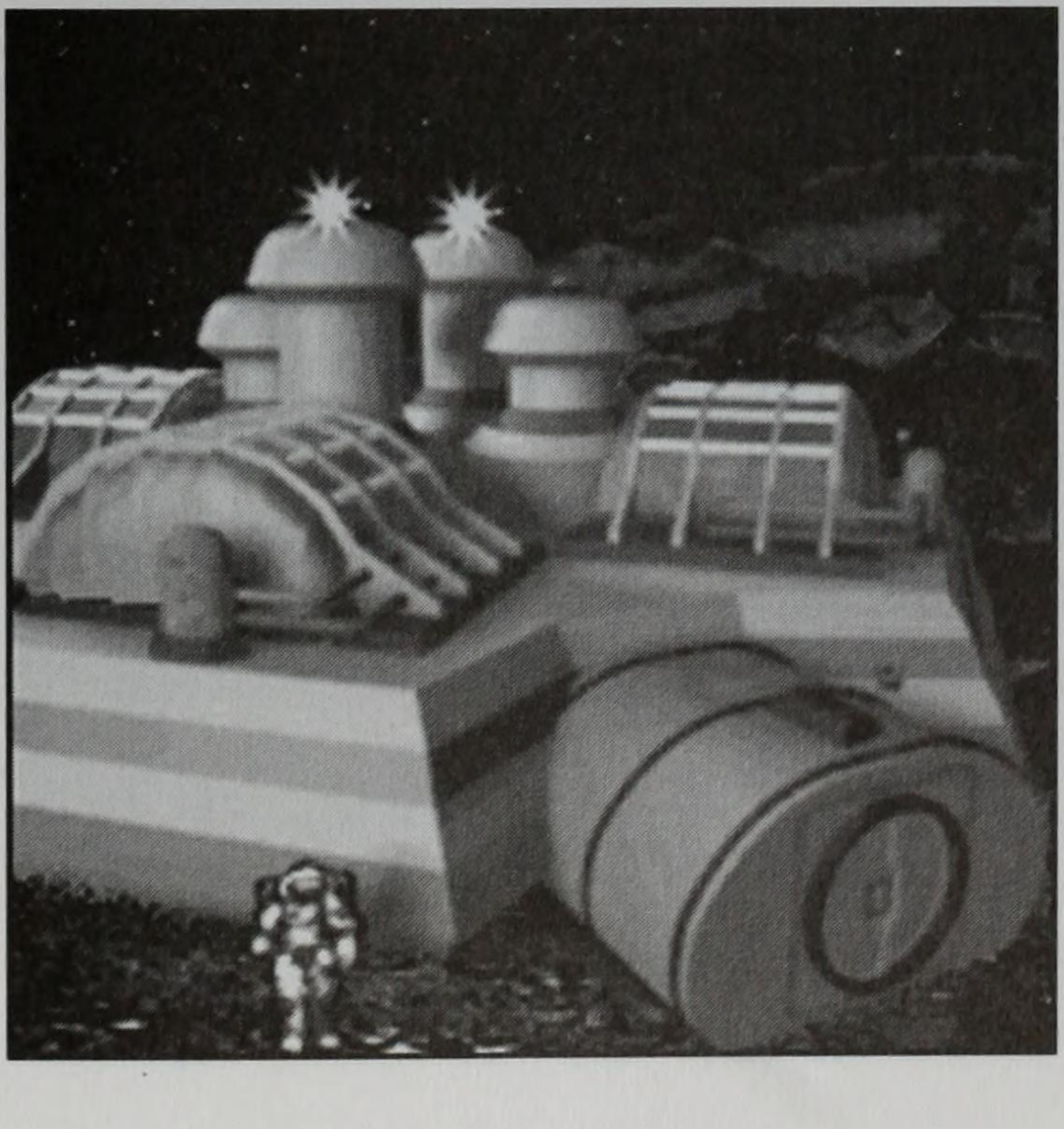
Trucks or a monorail are used to transport ores to the smelter, where an entire load is processed during one turn, after which the processed resources must be shipped to colony storage tanks to become available for use. Smelters have a limited storage capacity, so processing will cease if the storage bays are full. As soon as the storage bays are unloaded, processing can begin again.

CHAP

The Closed Habitat Atmospheric Production (CHAP) facility is necessary to produce a breathable environment for most of the colony structures. The CHAP facility, shown in Figure 10-4, is not to be confused with the terraforming facility, which is a high-tech research development that allows an atmosphere to be generated for the entire planet. Certain structures, such as those used while building the colony, have self-contained environments that do not require connections to the CHAP facility. Remote facilities are also able to support themselves without a CHAP connection. One CHAP facility is sufficient to generate the breathable gases for a large colony, but you may find it more convenient to build several to be shared by large groups of buildings. Having multiple CHAP

Figure 10-4

CHAP facility



facilities also reduces the possibility of losing your contained atmosphere in the event of a catastrophe.

SPEW

The Sewage Processing and Environmental Waste (SPEW) facility, as shown in Figure 10-5, is used to recycle basic wastes as well as building materials from structures you've chosen to destroy. When you place a bulldozer on an existing structure, the building is flattened and the materials are shipped straight to the SPEW facility. If no SPEW facility exists, the materials from destroyed buildings are lost.

The main advantage of recycling in this fashion is that useful resources can be used again, which also has the effect of improving Morale by one point per turn when the SPEW is operating. One recycled building produces 1 unit of valuable MPG (multipurpose goo), a special synthetic resource that is used in emergencies to replace any other resource required to maintain the functional status of an existing structure.

Terraforming Facility

Not to be confused with the CHAP facility, terraforming facilities are a high-tech development generated through extensive research. They allow you to create a breathable atmosphere on appropriate planets (see Chapter 23 for details). This process takes a long time, but the immediate benefit is 5 points added to Morale every turn

Figure 10-5

SPEW recycling facility

that a terraforming facility is operating. You can read more about the terraforming facility in Chapter 23.

Factory Management

Okay, you've done your research on efficiency and you've developed your colony to the point at which new factories become available to you. Your old factories are doing fine, they have the occasional breakdown, but you always manage to get things repaired. Your factory workers seem to be happy as long as you provide them with air and food (I did use the word, "seem," in that sentence, didn't I?). Maybe you've got a few robots working in the factories as well, and you've found that they never complain even though you make them work 24 hours a day.

The question is, now that you have a new factory type available, should you mess around with the existing system? After all, it's going to cost something for you to build a new factory. The answer is yes. When you have a chance to advance the technological level of a factory, bulldoze the old factory and build a new one to produce the same items. Not only will the new factory work better, with fewer breakdowns, and run more efficiently while producing at a higher rate, but the materials from the old factory will be recycled. This is progress. Your workers will enjoy working in the new environment, so they'll produce more as well.

When raw resources are low, or if you want to focus your available resources into certain areas for a few turns, you will find an advantage in shutting down the production at some of your lower priority facilities. Resources are distributed to each building according to the perceived importance it has in keeping your colony functional, but you have the ability to redefine the priority of an individual factory type or other facility each turn. There may be times when you can reduce food production so that the raw resources required to maintain the agricultural domes will be redirected toward building new structures or to factories making robots. Perhaps you want to have a sudden burst of luxury item production to control dropping morale, so you pause the operation of your robot and road factories to make sure that the flow of resources to your luxury factories is unrestricted. When you make this sort of priority change, you just have to remember to change things back to normal later if your life support systems or food production is going to be affected.

In managing your factories, and the rest of your colony, you must always try to keep the morale of your population as high as possible. Morale has a direct effect on factory production quantities. Make your workers happy and they'll work harder for you out of loyalty and the wish to gain your approval so that you'll make them even happier. Even though you can't have a direct effect on the way your workers do most of their jobs, you can make sure that they have a nice environment to work in, air to breathe, food to eat, plenty of space to live in at home, and the security of a low crime rate in the colony.

You also have the option of producing luxury items and distributing them through your commercial facilities. This is one of the most direct ways to affect the morale of the whole population. These people are living in a difficult situation, trying to survive on a hostile planet, trying to raise families under austere pioneer conditions, and living with the knowledge that if the colony fails, they will all die. They have given up all responsibility for controlling the siutation, leaving the decisions to you as their most qualified leader. They also know that there is no help available from the outside and that they can't return to the destroyed home of your civilization.

As you might expect, this situation leads to a certain amount of tension among the population. They spend a lot of time working so that they don't have to think about the situation. They really appreciate it when you create luxuries to distract them, allowing them to have some fun for a change.

There is an opposite side of the coin. If you don't make your population happy, factory production will drop, research progress will drop, and morale will drop even faster. The only thing that will increase is the level of criminal activity in your colony. If morale stays low for too long, your colonists will start looking around for other options. They know they can't leave the planet, so there are really only two paths open to them: they can defect to the rebel colony that split away from your group when you arrived at the new planet, or they can cause civil unrest and feed on themselves.

Humanoid robot workers, developed through extensive research in robotics and other areas, are also appreciated by your population. Most of your population is composed of scientists or the children of scientists who settled the new planet, so they are vastly overqualified for factory work. They do factory work because they realize that it's necessary to the continued survival of your colony, but they envy those who are able to do scientific research in the laboratories you've established. They believe that the increasing number of robot workers in the factories will make an increasing number of research jobs available. In fact, this is true, because humans are much better suited to research than robots or even the artificial intelligence personalities. AIs are not as capable of abstract thinking as the humans, as well as scoring zero on their intuitive thinking skills. So, the more robot workers you place in factory jobs, the more humans will be available for research, which means research progress will advance much faster, which means the level of morale will go higher, which means your colony will advance faster. To sum it up, I think we can define this progression of results to be a good thing.

This chapter has given you the details of factory production and management. Not only have you learned how to balance production to meet your needs, but you have also been given an insight into the thinking processes of your human workers and what they seek in life. The issue of storage, which can stall the operation of several production facilities, has also been addressed. Because your colonists are captive consumers, there is no need to market your products and get them accepted, so at least you don't have to worry about that for a few years.

The next chapter goes into more detail on the subject of robots. Are they really our friends? Can you use them to rule the world? How can you apply them to the problems of your colony in the best possible way? What does Isaac Asimov have to do with it anyway? Are humans superior to robots in all things? Why are robots so popular? Can a robot replace you? Am I actually a robot? Do androids dream of electric sheep? These burning questions, and more, are answered in the next chapter.

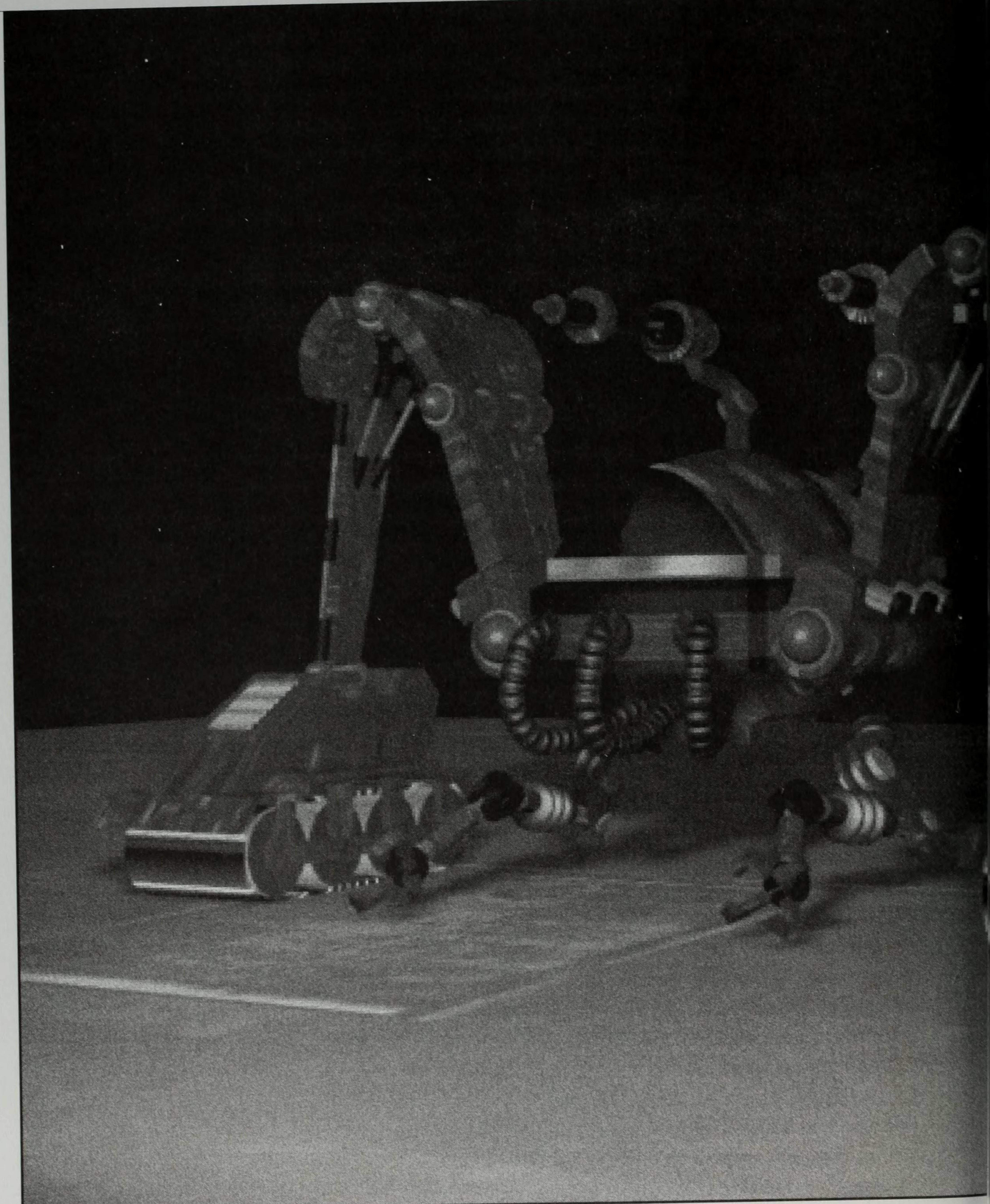
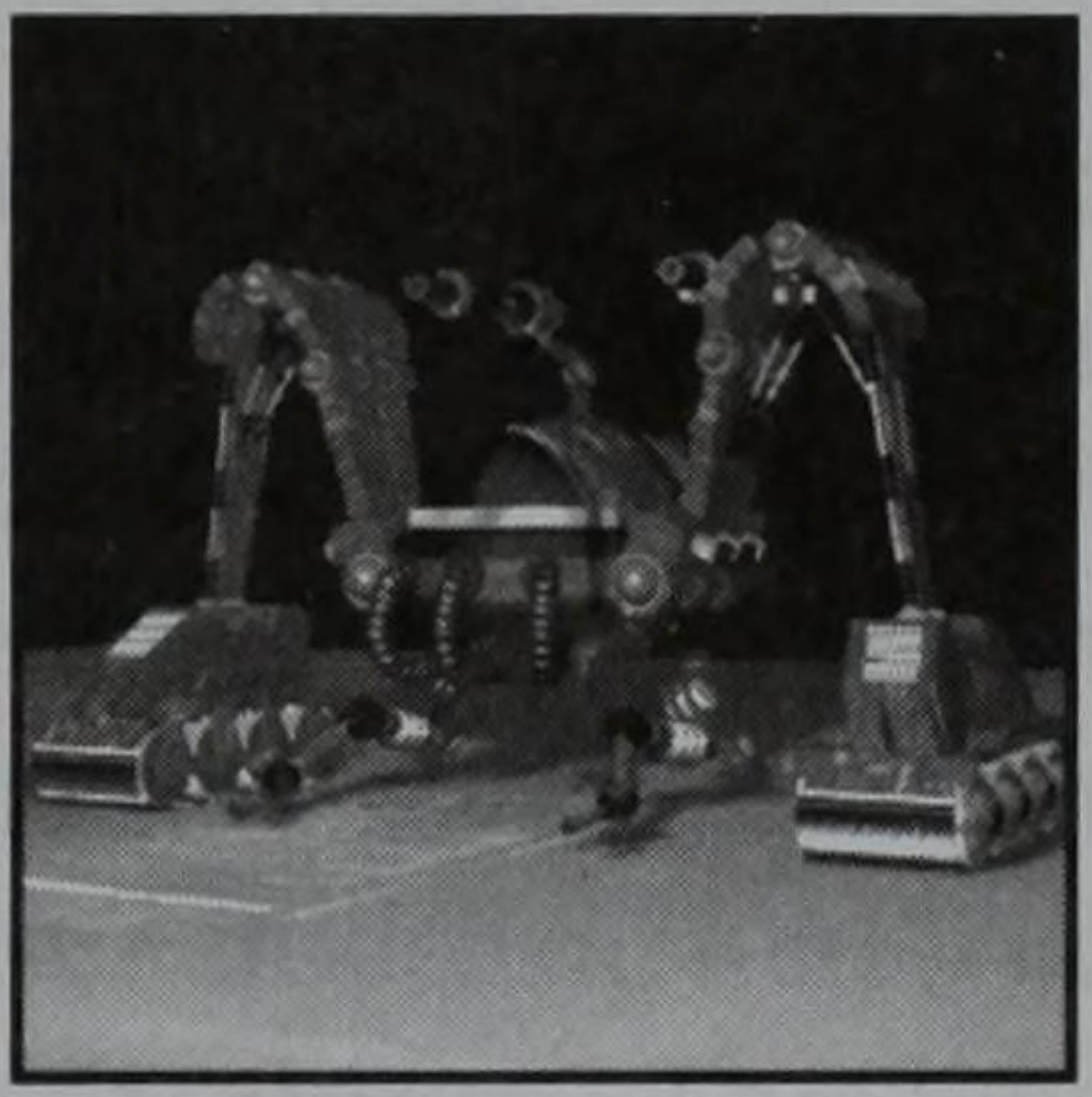


Figure 11-1 Lawbot

11



Robots

> *The future holds very little hope for those who expect that our new mechanical slaves will offer us a world in which we may rest from thinking. Help us they may, but at the cost of supreme demands upon our honesty and our intelligence. The world of the future will be an ever more demanding struggle against the limitations of our intelligence, not a comfortable hammock in which we can lie down to be waited upon by our robot slaves.*
>
> Norbert Wiener, *God and Golem, Inc.* (1964)

In 1920, Czech playwright Karel Capek wrote a play called *R.U.R.*, in which the initials stood for Rossum's Universal Robots. This play introduced the Czech word, *robot*, meaning "serf," into English. Since then, robot has been used to describe a machine that can perform human work. *Robotics*, the study of robots, was a term coined by Isaac Asimov in his *I, Robot* stories. Fictional robots tend to appear humanoid in shape, but the term now applies to a variety of mechanical devices that operate like human body parts, such as the robot arms used by car manufacturers.

In *Outpost*, most of the robots serve specialized functions that would otherwise have to be performed by humans. The humanoid worker is the most advanced robot in the game, and also the least specialized. Figure 11-2 shows one of the happy welder robots used during the starship construction phase.

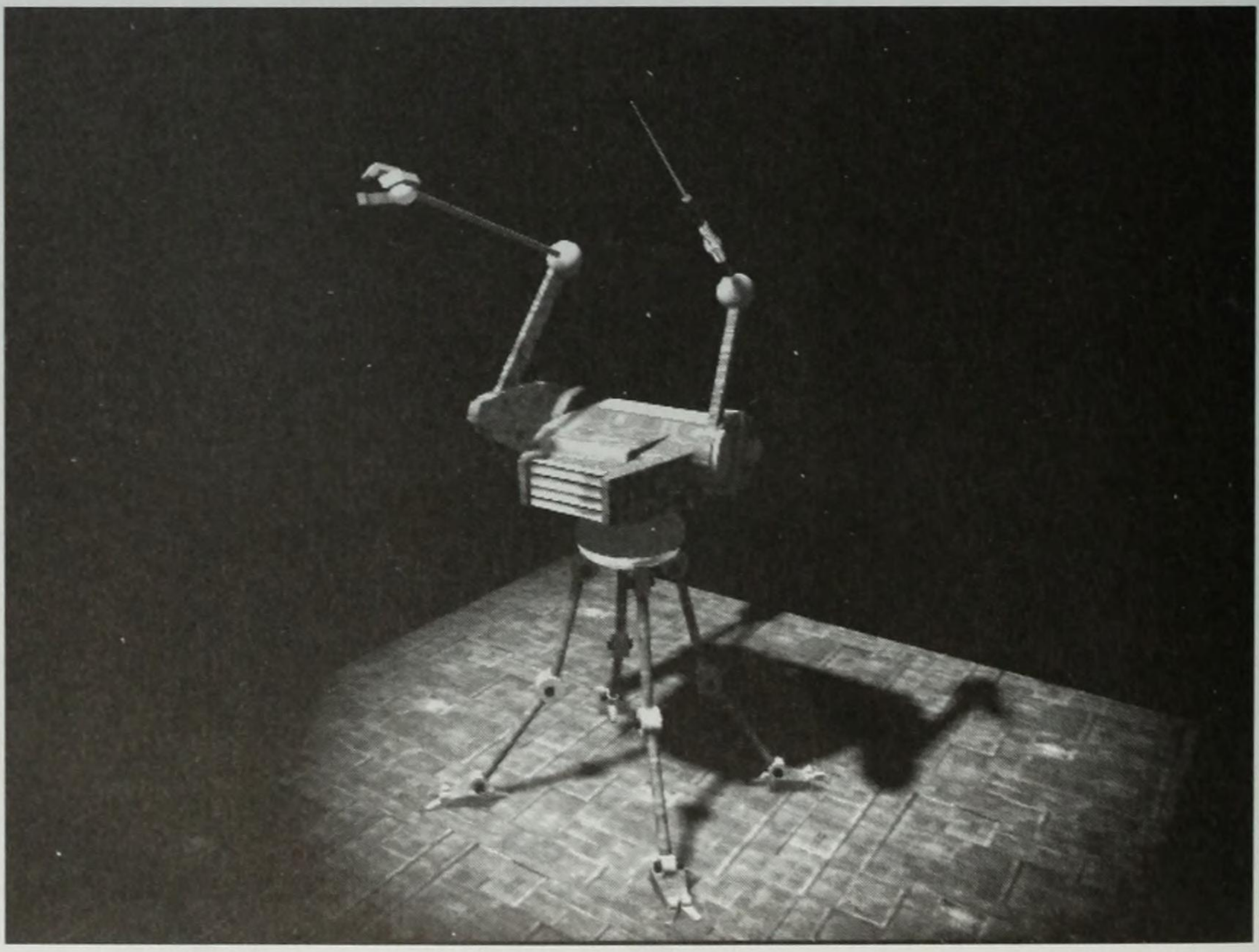
This chapter discusses the advantages and disadvantages of robots in *Outpost*, the types of robots you can build, and the types of new robots that can be generated through research.

Robots or Humans?

Humans are fragile creatures. Average humans require a specific mixture of gases to breathe; they can tolerate only a narrow range of temperature and barometric pressure; they get sick, depressed, angry, old, and tired; they expect to be paid for their work; they

Figure 11-2

A welder robot in a candid pose



have to keep eating to function; and they break easily. A potential employer should think twice about employing a human when a robot is available to do the same job. However, robots can't do everything. For example, the abstract and intuitive thinking required in scientific research must be performed by humans. It would also be difficult for a robot to perform the functions of a homicide detective, although a police robot or "lawbot," as shown in Figure 11-1, would be possible.

In *Outpost*, you start out with a limited set of robots, but time and research allow you to develop advanced models that can perform increasingly complex functions. The following are your choices.

Robodozer The bulldozer robot is used to prepare a foundation for building. Used both on planet surfaces and underground, it flattens the terrain and uses a special sealing material that serves as a foundation for further construction. The length of time required to bulldoze a new tile is dependent on how hard the terrain is at that location. Robodozers can also be used to create "dirt roads," by bulldozing terrain in a straight line to specific locations, shortening travel times for your robots and other vehicles. Road material can be laid down on these dirt roadbeds to create a paved Road for faster vehicle movement.

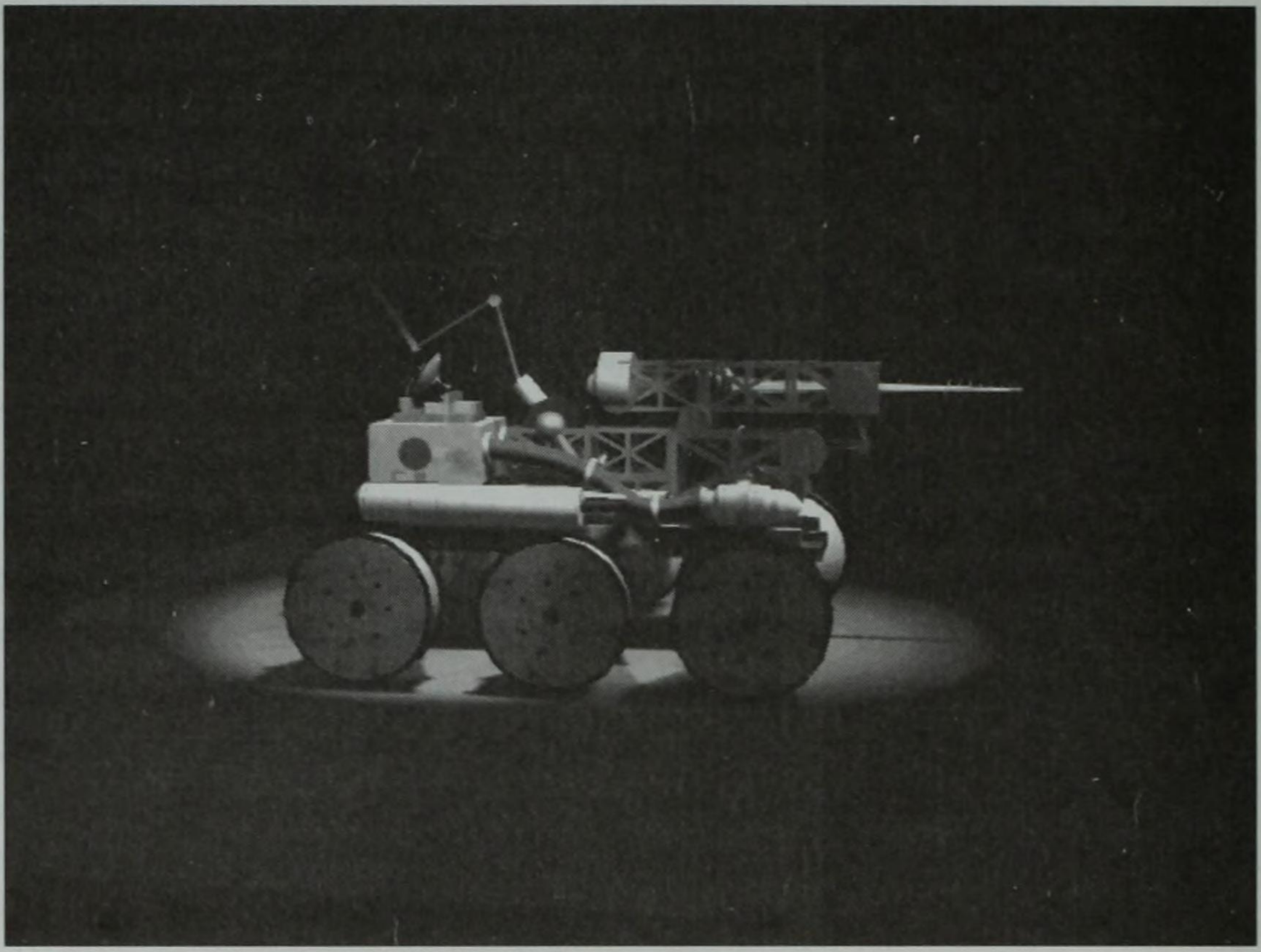
Robominer The miner robot is able to dig Mine Shafts, reinforce them, pressurize them, locate mineral deposits, build ore elevators, and cap off the mines with storage facilities. The amount of time it takes to dig each level of a mine depends on the type of terrain. Obstacles and the maximum digging depth of a particular planet are also able to block progress by the robominer. Because the robominer search capability is not as sophisticated as that of a roboexplorer, it can home in only on existing mining beacons. See Figure 11-3 for an example of a robominer.

Robodigger The digger robot is used to create the underground living areas of each colony. It can operate in a vertical or horizontal mode, depending on what you choose. As it digs out an area underground, its immediate surroundings come into view, while the rest of the unexplored underground terrain remains black. Care must be taken not to tunnel into an existing Mine Shaft. See Figure 11-4 for an example of a robodigger.

Roboexplorer The explorer robot is designed to wander around on the surface of the planet, seeking new locations for mining. If it explores a location that the starship has identified as having good potential for mining, the explorer will sample and scan the ground

Figure 11-3

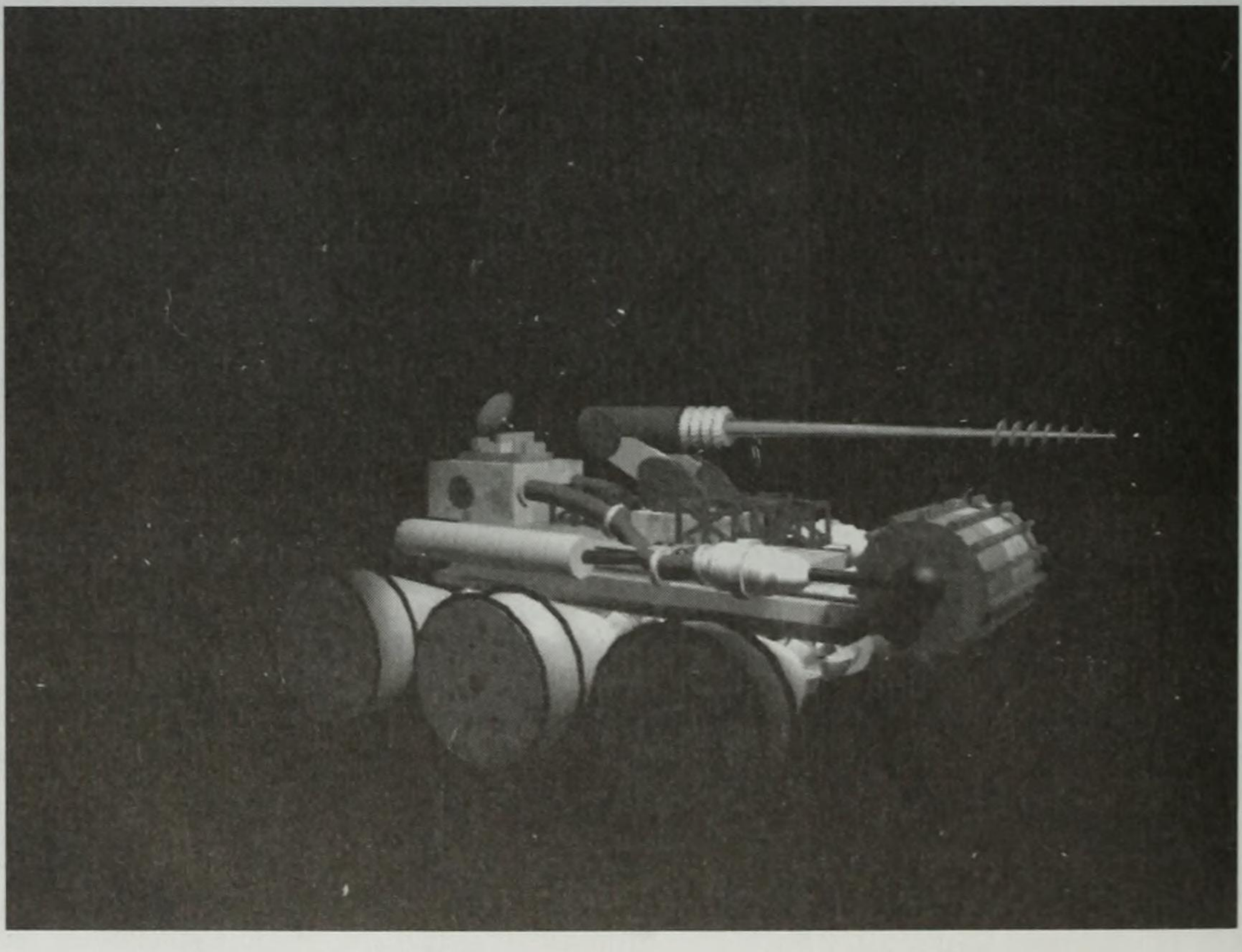
Robominer



to learn the exact concentrations of raw resources. If it identifies an unmarked mining location, the explorer will also mark the position with a red mining beacon so that a robominer can find it.

Figure 11-4

Robodigger

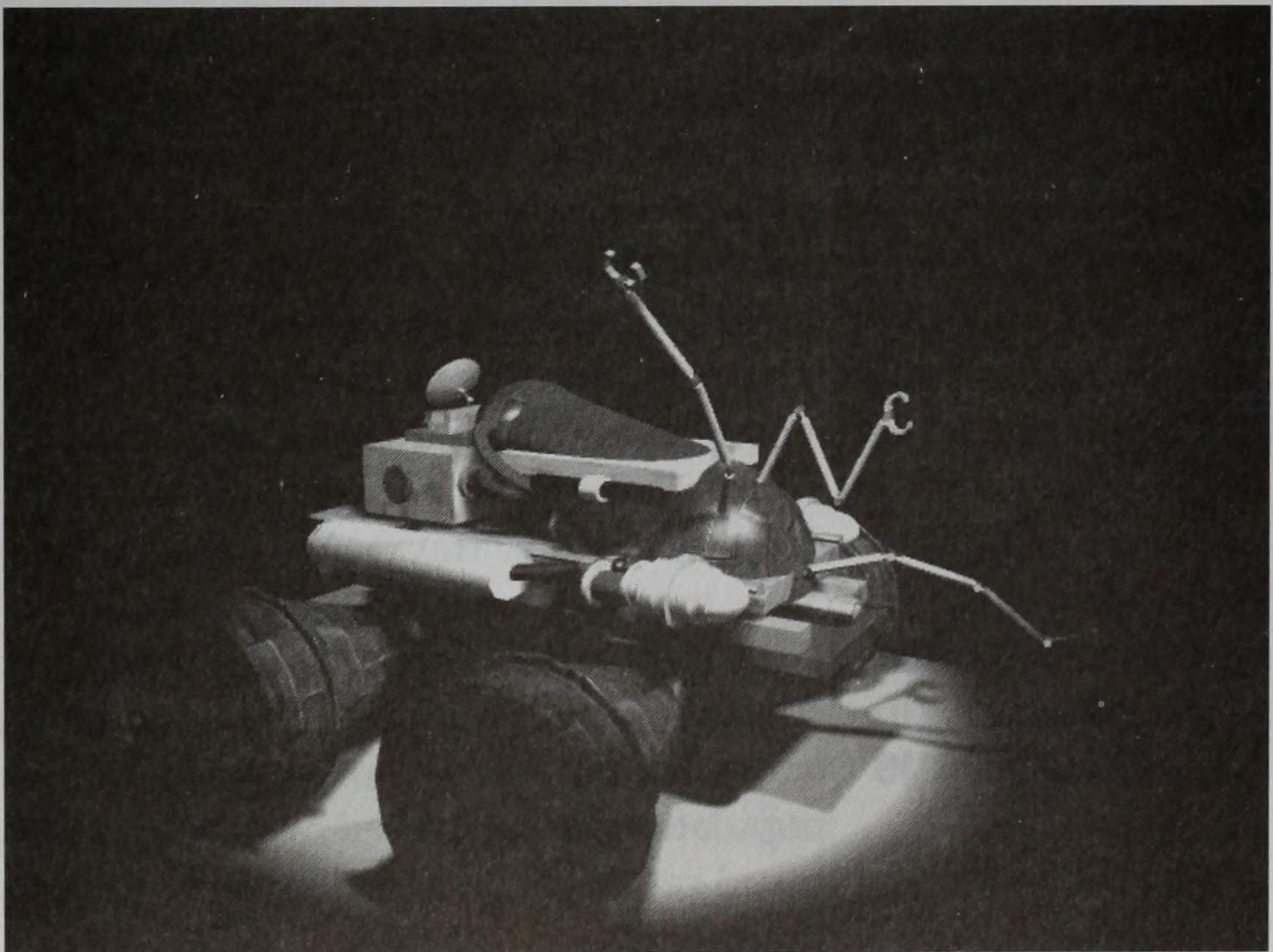


Repairbot The repair robot is a sophisticated device, assisted by human telepresence, that seeks out incapacitated robots and fixes their problems when possible. Cell replacement is one of the functions served by repairbots, who can go straight to the site of the "dead" robot and give it new life, as long as a fresh fuel cell is available from storage. Repairbots can also fix broken robots if a supply of robot spare parts has been built by a surface factory. This is one of the robots that can be generated through research into robotics. See Figure 11-5 for an example of a repairbot.

Airbot The airborne robot is a rocket-powered drone with cameras. If you don't have an orbital observer satellite to keep a constant eye on the activities of the rebel colony, you can send an airbot over their colony to get a one-time look at their structures. The Site Map location of the rebel colony must have already been discovered by the orbital observer or a robot explorer before an airbot can be targeted on it. Consider each airbot disposable, because you won't be seeing it again once you've used it. This is another type of robot that can be generated through research in robotics.

Microbot The microbot represents a class of small robots that are small enough to work their way into machinery to help keep it from breaking down. This type of robot is generated through

Figure 11-5
Repairbot



research in robotics and entomology. After you've discovered microbot technology, your factories will decay at a slower rate so that you'll have fewer breakdowns.

Lawbot The law robot, or police robot, has a greater law enforcement effect than a human policeman because it can be targeted for a direct hit on a crime area. Crime at the target location, a Red Light District, will cease for 10 turns, after which the lawbot is destroyed. The positive morale effect from the Red Light District will also stop while the lawbot is present. The 10-turn delay also gives you plenty of time to build a Police Station beside the Red Light District if you want a permanent solution to the crime at that location. Remember that a lawbot can be targeted only to a Red Light District, so that it won't run amok through your colony. See Figure 11-1 for an example of a lawbot.

Humanoid Worker The humanoid worker replacement robot enters the worker pool as soon as it is built. As each worker robot enters the workforce, a human is freed up for reassignment to a scientific job in a research laboratory, assuming such a position is available. The robot population can have a tremendous effect on morale among your colonists, as well as increasing the efficiency of your factory production. Extensive research in robotics must be performed to perfect the humanoid worker design, allowing it to be produced by your robot factories.

Terrain Effects on Robot Travel

Travel times for individual robots and other vehicle types are given in Table 11-1. Terrain effects are considered in the travel time, but delays due to working road crews are not. In general, ground robots move twice as fast on "clear" terrain as they do on "rough" terrain. On a bulldozed, but unpaved, road these robots move three times as fast as they do on rough terrain. On a paved Road, these robots move four times as fast as they do on rough terrain. Vehicles that move through the air are, of course, unaffected by terrain types. Trucks and monorails are discussed in more detail in the next chapter, but their travel times are shown here.

It's Hard to Get Good Help These Days

Robots are handy to have around, but they have their limits.

A factory can produce only one robot type at a time, but it can build them at the rate of one every five turns. The active robot population is also limited by fuel cell production and Robot Command capability, in addition to the need for the basic resources to produce them.

Table 11-1 Distance (in Tiles) Covered per Turn per Terrain Type

Robot/Vehicle	Rough Terrain	Clear Terrain	Dirt Road	Paved Road
Robodozer	1	2	3	4
Robodigger	1	2	3	4
Robominer	2	4	6	8
Repairbot	2	4	6	8
Roboexplorer	2	4	6	8
Lawbot	3	6	9	12
Airbot	5	5	5	5
Truck	1	3	4	5
Monorail	6	6	6	6
Low-orbit freighter	10	10	10	10

Fuel cells are produced at the rate of 1 every 10 turns. One fuel cell is required to power each new robot. Every fuel cell that has been used in a robot for 200 turns must be replaced by a repairbot. If a robot's fuel cell fails in the field, Robot Command will receive an alert so that a repairbot can be dispatched to make repairs.

A Robot Command facility is necessary to control your wandering robots. All robot control functions are handled from this location, working closely with the Communications Tower signal relays. Signal strength varies according to local planetary conditions, so if you're losing contact with a lot of your robots, build more remote Communications Towers. Communications satellites in orbit and research in Harsh Environment Signal Processing can also widen the area covered by your communications system.

Wandering robots can be lost if they come across unexpected holes or cliffs in the terrain. There's not much you can do about this except to keep building more robots to replace those that you lose.

Now that you know the intimate details of the *Outpost* robots, it's time to look at the transportation system. What's the best way to move resources around? How can you move colonists from one colony to another? Can you call a cab to drive you home after a wild night at one of the Red Light Districts? Those questions, and more, will be answered in the next chapter.

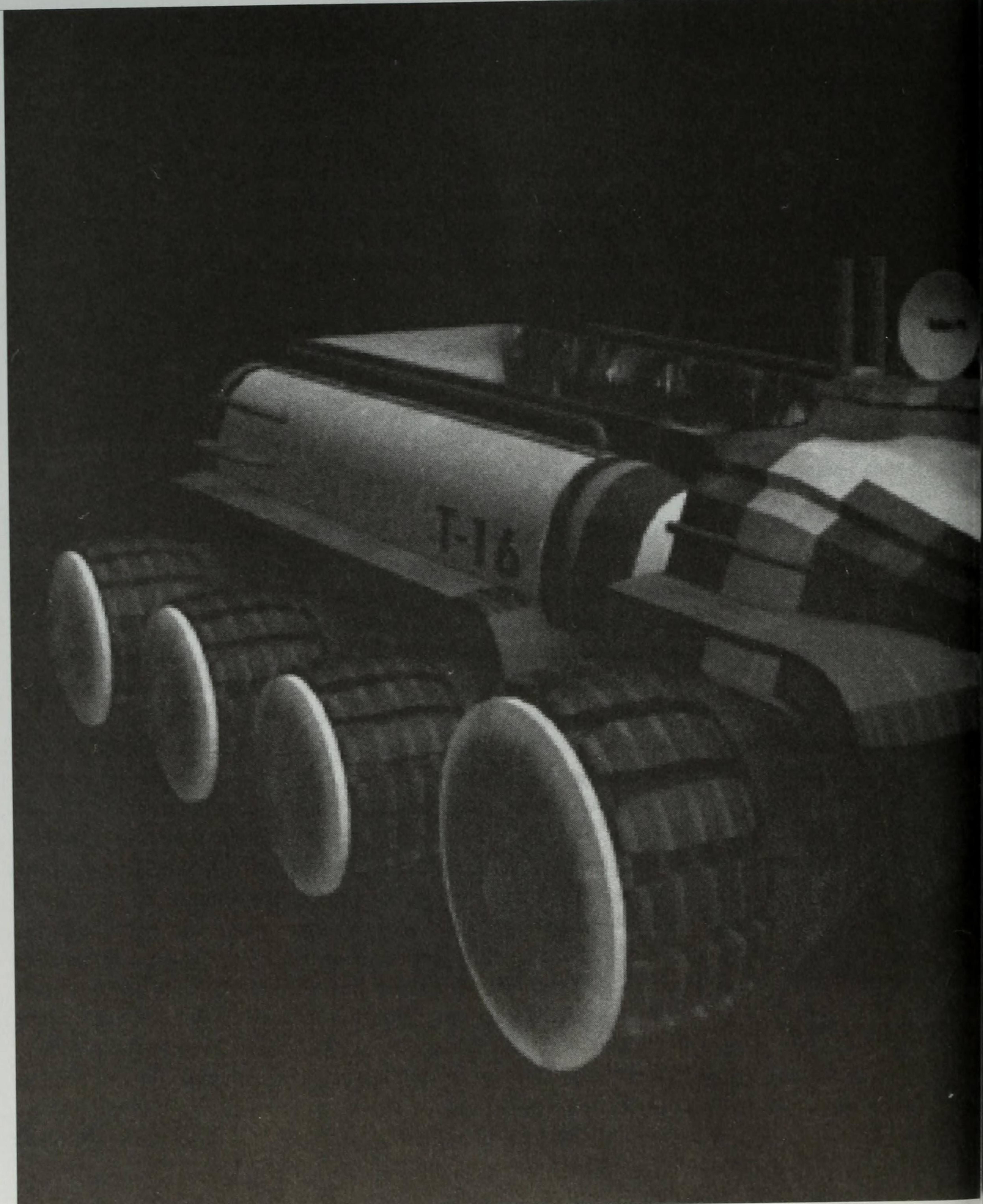


Figure 12-1 Semiautomated truck

12

Vehicles

I don't even like old *cars…I'd rather have a goddam horse. A horse is at least* human, *for God's sake.*

J. D. Salinger

Your colonists are a sturdy bunch, but you can't depend on them to haul ore from the mines to the Smelters, or from the Smelters to the colony Storage Tanks, or anywhere else, for that matter. In fact, your colonists have a definite aversion to stepping outside, even on the nicest day. Your semiautomated trucks and your monorail system are your only safe means of moving resources and people across hostile planetary surfaces.

This chapter will point out the good and bad points of your transportation options. Careful planning will allow you to make the best use of road materials, shipping points, centralized smelters, and looping monorail lines. Poor planning will lead to chaos, redundancy, runaway expenses, shipments blocked on roads, perhaps even doom for your colony.

The Roads Must Roll

Dirt roads allow your trucks to make faster progress, while paved Roads move them along at great speeds...unless they happen to run into a union road crew taking a break. When they're on one of their many daily breaks, while building or maintaining a road, a road crew will block any of your trucks that happen to come along. When the blockade is removed, your trucks will be allowed to continue.

A road crew is composed of six people: one to drive the road-building truck, one to navigate the road-building truck, one to make coffee for the crew of the road-building truck, one union observer to make sure that all breaks are taken on time, one to operate the safety warning lights for the blockade, and one to remove the safety warning lights from the blockade.

The advantage to the road crew is that they will start working as soon as you assign them to a job by placing a Road on the map. The supply of road material is produced at the rate of 1 unit per turn by the factory, which is shipped automatically to the work site. A Road takes two turns to complete, which allows the road crew time to take all of their breaks.

Trucking

The semiautomated trucks, as shown in Figure 12-1, operate with a modest amount of artificial intelligence and a large amount of human input through telepresence. This combination gives each truck the capability to move its load efficiently to its destination with the best possible speed and safety. Table 11-1 shows that, for each game turn, a truck can cross over one rough terrain tile, three clear terrain tiles, four dirt road tiles, or five paved Road tiles.

You will find that it makes good sense to centralize a Smelter so that it can receive loads from several mines with a minimum of distance for the trucks to travel. The faster you can get a load to a Smelter from a mine, then truck it to colony Storage Tanks, the faster those resources will become available for use. Smelters are complicated facilities, so you should also spread enough of them around so that backups exist if one of the Smelters breaks down.

Remember that the storage capacity of an active mine is limited to 500 units of ore. When the maximum storage capacity is reached, the mine will shut down until the ore is removed from storage by truck or by monorail. Each truck can carry 100 units of ore or processed resources. A typical route will take the empty truck to the mine, where it will be loaded with ore, then to the Smelter, where it will drop its load of ore and pick up a load of processed resources for delivery to colony Storage Tanks. Once the resources have been loaded into the storage tanks, they become available for use by the colony that owns those Storage Tanks.

Monorails

The monorail, shown in Figure 12-2, can carry people, but its main job is to carry resources around on the planet as fast as possible. The monorail also makes intercolony connections easier. Monorail lines are expensive to build, but road crews can't stop a moving monorail, breakdowns occur less often than they do with trucks, they carry bigger loads than trucks do, and they can be set on continuous loops to connect mines with Smelters, Smelters with colony Storage Tanks, and colonies with colonies.

Because a monorail is situated on a track high above the ground, it's able to move at a continuous speed of 6 tiles per turn. Once it's built, terrain has no effect on a monorail line.

Figure 12-2

Monorail passing through town

A monorail can carry 500 units of ore to the Smelter, so you may find it useful to build a monorail line between several active mines and a centralized Smelter. This monorail can make regular runs, perhaps making its pickups when each of five mines has 100 units of ore sitting in storage, then taking the load to the Smelter for processing. In the same way, another monorail line could connect the Smelter to your colony's Storage Tanks, making the processed resources available for use at a faster rate.

Monorails sound wonderful, don't they? Well, they also have their drawbacks.

Although it doesn't happen often, new planets sometimes harbor germs that are completely alien to human biological systems. The introduction of such a germ into the closed environment of your colony can have devastating effects. If you haven't prepared for this eventuality by doing enough research to discover the antidote to the alien virus, then you won't have produced a stockpile for emergencies, which means your entire population might be wiped out. If the plague is contained at one of your colonies, and you have others that are unaffected, you may lose only part of your population.

Now, you may be wondering why I'm mentioning this plague business in the transportation chapter. If you have a working monorail connection between your colonies, the plague has an excellent chance of spreading from colony to colony, happily destroying your population as it goes. This can be quite disturbing, particularly if you had planned to be successful at this game.

As with everything else in the game, there are good and bad points to the plague. If you've got a monorail connection with the rebel colony due to regular trade agreements, but they've been annoying you lately with their hard bargaining position, you can get the plague, pass it on to them, take the antidote yourselves, and wipe out the rebels unless they've already discovered the antidote. This is known as the "Typhoid Mary Gambit," discussed in more detail in Chapter 20. It's a sneaky and underhanded way of doing business, but that's your decision. Of course, this plan might backfire on you, and you might lose your colonists before the plague spreads to the rebel colony, so decide with care before you start flinging germs around.

This chapter has given you a few pointers regarding the logistics of transportation on a hostile planet. Roads and monorail systems may be built only to be destroyed by heat, pressure, earthquakes, dust storms, or the whim of the game designer. There are times when the planet will win, if only because it's tougher than your colonists, but it makes success much sweeter when you're able to overcome the enormous obstacles to survival.

The next chapter will strive to explain everything you ever wanted to know about satellites, probes, and the possibilities of orbital data gathering from the starship. *Outpost* continues the long and successful tradition of using spacefaring robots to blaze safe trails for humans. The robots have never complained about being sent on dangerous missions in space, so we'll keep doing it until they develop enough artificial intelligence to make us stop.

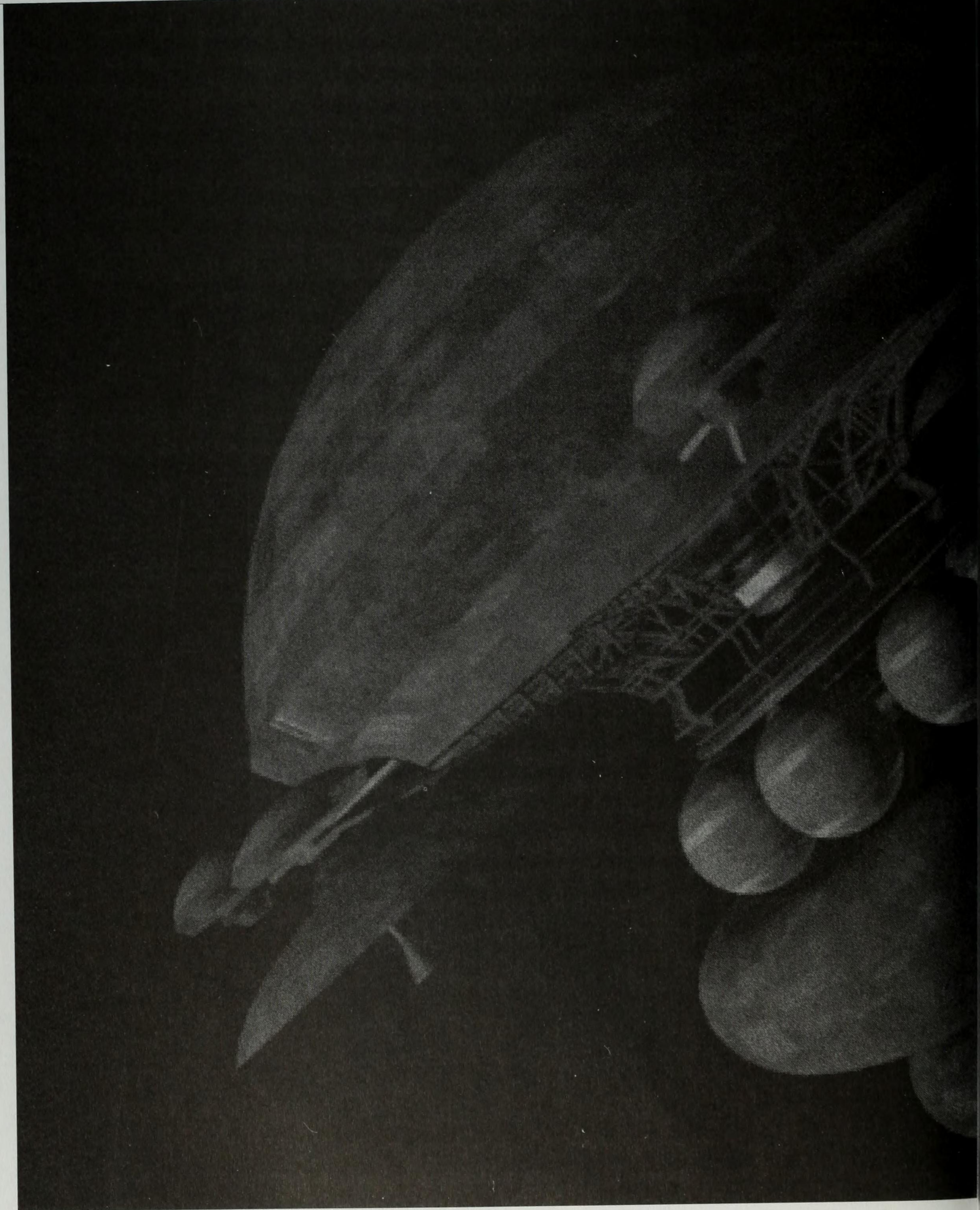


Figure 13-1 Interstellar flyby probe

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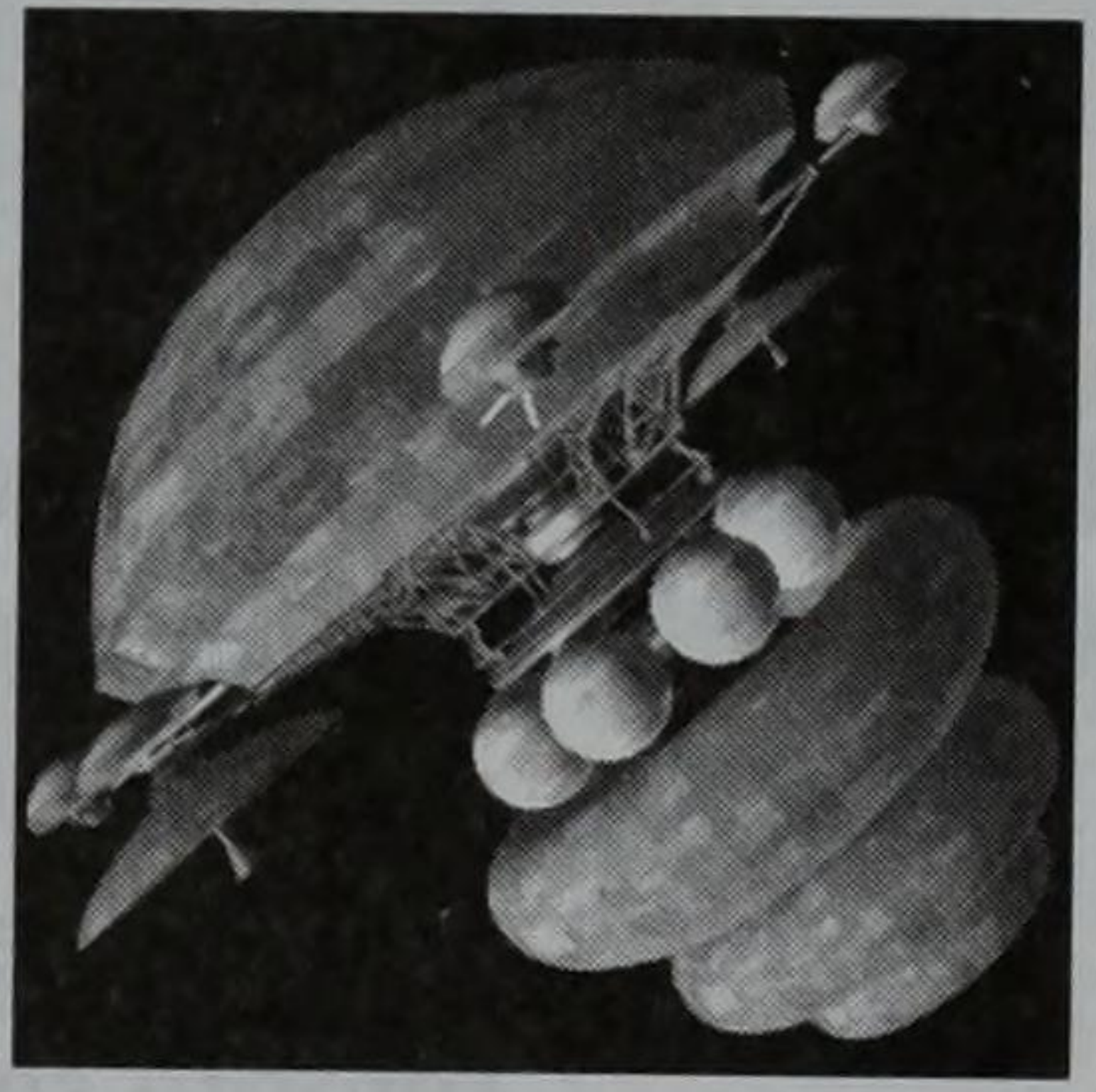


Satellites and Probes

Finally we shall place the Sun himself at the center of the universe. All this is suggested by the systematic procession of events and the harmony of the whole universe, if we only face the facts, as they say, with our eyes open.

Copernicus,
De Revolutionibus Orbium Coelestium (1543)

How do you get to know a planet? Astronomers do it with optical and infrared instruments. Planetary scientists do it with probes and satellites. Thousands of weather, navigation, and spy satellites orbit the Earth every day to keep track of local conditions, and these types of satellites could be used in orbit around other worlds as well. This chapter introduces you to the concept of remote sensing and what it means to you. The development of robotic space exploration is also discussed, because it has a direct bearing on the technologies we've developed to study other planets.

Don't Leave Home without Them

When you are presented with the option of taking a variety of satellites and probes with you on the voyage to your new planet, you should give careful consideration to the type of information you'll need to make intelligent decisions. The starship itself has remote sensing capabilities that will give you basic survey data about the topography, chemistry, and geology of your planet. These data will be analyzed by the artificial intelligence and presented to you while you're still in orbit, allowing you to choose the best possible landing site. Locating the nucleus of your colony near a good mineral deposit is often a good idea, but there may be tradeoffs to consider regarding the difficulty of the terrain surrounding the mine or the geological activity in the area. Placing your colony on easier terrain that's too far away from the mineral deposits may result in problems with transporting the mined ore. A thorough study of the planet from orbit helps guide you toward intelligent landing sites.

At the beginning of the game, very long baseline interferometer (VLBI) probes are automatically launched to gather data about star systems you want to investigate. This level of information can be supplemented with ultra long baseline interferometer (ULBI) probes and interstellar flyby probes. Each type of probe can provide you with greater detail about the star system you have chosen to colonize, warning you about the types of planets to be found there and other local conditions. If you're more of an adventurer, you can let the artificial intelligence on the starship choose your destination.

Robots in Space

To understand the capabilities of the far-flung robot senses we've created, and the step-by-step methods we've used to explore the solar system, let's take a quick look at the past.

What follows is a brief history of the highlights in robotic space exploration. This is not meant to be a comprehensive list, but it gives you an idea of when certain goals were reached as well as the progressive development of our unmanned space program. This is an informal history, so I've taken the liberty of inferring certain reactions by the humans and robots involved in these historic events.

1957: The space age begins when the first artificial satellite, *Sputnik 1*, is placed in orbit by the Soviet Union on October 4. Our German rocket scientists get very annoyed with their German rocket scientists.

1958: *Explorer 1*, the first American satellite, is launched on January 31. Wernher von Braun thumbs his nose at the U.S.S.R.

1959: The Soviet Union sends *Luna 3* to the moon. The first images of the lunar far side are transmitted back to Earth. The composition of the photos isn't very good, but it's understandable in the excitement of the moment. *Luna 3* receives a good score for effort.

1962: The United States sends *Mariner 2* to Venus. It's the first successful flyby of another planet. There are ugly rumors that *Mariner 2* is fleeing from the Internal Revenue Service.

1965: The United States sends *Mariner 4* to Mars. Like a tourist with a new camera, it sends back some blurry photos of craters on its flyby.

1966: The Soviet Union sends *Luna 9* to the moon. It lands, buys some postcards, and sends those back to Earth as the first photos from the lunar surface.

1967: The Soviet *Venera 4* tries to land on the surface of Venus. Descending by parachute through the thick, hot atmosphere, it realizes it has made a big mistake. Hot lumps of the former *Venera 4* strike the surface.

1969: *Apollo 11* goes to the moon. Neil Armstrong blows his lines while billions watch on television, but it's understandable in the excitement of the moment. Jealous, the remaining *Mariner* probes say they could have done a better job. (*Apollo 11* wasn't a robot, but I wanted to mention it just for reference. Odd to think that it was 25 years ago.)

1970: The Soviets try again with *Venera 7*. It makes the first successful planetary landing on Venus and transmits data from the surface. This is the first confirmation that McDonald's has not yet sold hamburgers on other planets.

1970: A busy year for the Soviets. *Lunokhod 1*, a moon rover with wheels, is the first mobile robot on another world. It is unable to find any drive-through fast food.

1971: *Mars 3* sends back 20 seconds' worth of data from the surface of Mars, but it's all in Russian. There is speculation that it's a form of social protest.

1971: The U.S. *Mariner 9* orbits Mars and spends a year mapping the planet. It seems quite surprised when NASA says it won't be coming back.

1973: *Pioneer 10* flies past Jupiter and claims it for all robotkind.

1974: *Mariner 10* flies past Mercury and sends back photos. As the first spacecraft to reach Mercury, it tries to claim the planet for itself.

1975: *Venera 9* sends back the first photos from the surface of Venus. There is speculation that the photos were purchased from a passing extraterrestrial.

1976: Two *Vikings* land on Mars and claim the planet in the name of Leif Ericsson. For legal reasons, they photograph the surface and send the photos to their attorney. One cheesecake photo that makes it into the newspapers is a shot of one of their legs extended on the surface.

1979: *Pioneer 11* is the first spacecraft to reach Saturn, but it has some trouble remembering whether it's supposed to photograph the rings or give us a ring. Just to be safe, it snaps off a few candid shots and continues on its way.

1979: *Voyagers 1* and 2 photograph Jupiter as if they were interplanetary *paparazzi* shooting candid photos of a celebrity.

1980: Striking out on its own, *Voyager 1* does a serious photo study of Saturn. The big slick magazines, such as *Time* and *Newsweek*, publish some of these photos on their covers. *Voyager 1* is pleased by its success, but wonders when it will receive payment for its photos from the magazines. Its personal manager at NASA tells *Voyager 1* not to worry because "the check is in the mail."

1983: Having spent too much time alone in space, *Pioneer 10* decides to seek spiritual enlightenment by going where no robot has gone before—out of the Solar System.

1986: Having heard of its sibling's success, *Voyager 2* photographs Uranus. Art critics pronounce the photos "professional, but uninspired." Art galleries say they'll show the photos only after the artist is dead. Undaunted, *Voyager 2* resolves to keep trying.

1986: Halley's Comet is attacked by five space probes from Japan, Europe, and the Soviet Union. Japanese and European robots declare this feat a victory for their countries.

1989: A package of unmarked Neptune photos mysteriously arrives on the managing editor's desk at *Time* magazine. The envelope is torn and dirty after the long trip. The editor publishes the images and declares the mystery photographer a genius. The art critics go wild. Finally, a proud *Voyager 2* comes out of the closet and claims credit for the photos.

1991: The Unites States sends *Magellan* to map Venus with its radar. Thinking that it might be able to repeat the successes of the *Voyager* twins, *Magellan* takes a sensational slant at capturing "Venus underneath the veil." The *National Enquirer* turns down the photo series as being too risqué. *Playboy* suggests that *Magellan* keep the photos on file until Venus becomes more of a celebrity.

1991: *Galileo* gets the first close-up portraits of an asteroid, then continues its journey toward Jupiter. Having been snubbed by the Catholic church, which refused to accept *Galileo* as a priest on the grounds of being a robot, *Galileo* vows never to return to Earth.

1992: The Catholic church issues a formal apology to *Galileo*. Robots everywhere rejoice.

1993: *Galileo* returns to Earth for a gravity-assist maneuver, but doesn't stay very long before it leaves again.

1993: The *Mars Observer* protests budget cuts at NASA by shutting itself down and staying that way.

Orbital Data Gathering

On arrival at your new planet, the *Outpost* colonization starship has a limited number of sensory capabilities to be used from orbit. The artificial intelligence (AI) will activate these instruments when you arrive and help you study the incoming data. The AI will also use its vast knowledge of mineral resources and previous planetary landings to determine the best landing sites for your new colony. With the intent of studying the surface and atmosphere of the new planet before surface penetrators are used, this phase of the mission will have five primary objectives:

- Determine the global elemental and mineralogical character of the surface material.
- Define the global topography and gravitational field.
- Establish the nature of the magnetic field.
- Determine the time and space distribution, abundance, sources, and sinks of volatile material and dust. This includes the search for water.
- Explore the structure and aspects of the atmospheric circulation, if any.

The orbital data gathering will be accomplished with these instruments, which are in common use on current space probes:

- **Gamma ray spectrometer** Detects and measures gamma rays emitted by the planet's surface. These data will allow the AI to identify some of the chemical elements present and determine the amounts of each one, such as thorium, uranium, and most of the major elements.
- **X-ray spectrometer** Measures surface fluorescence induced by X-rays from the local star hitting the surface of the planet. These data will allow the AI to identify the presence of aluminum, magnesium, and other significant rock-forming elements.
- **Visual and infrared mapping spectrometer** Identifies the chemical composition of the surface and atmosphere by measuring frequencies of visible light and infrared energy emitted by them.
- **Magnetometer and electron reflectometer** Detects and measures any global or local magnetic fields. If the planet possesses a magnetic field, these instruments can study its interaction with the solar wind.
- **Planetary camera** Returns detailed images of the surface. This instrument consists of one high-resolution, narrow-angle camera and two low-resolution, wide-angle cameras.
- **Near-infrared mapping spectrometer** Measures temperature differences and determines the composition of the atmosphere and surface. This powerful imaging system can see through clouds that might block visible, ultraviolet, and many other wavelengths of infrared light.

- **Pressure modulator infrared radiometer** Measures thermal radiation from the atmosphere. It produces altitude profiles of temperature, water vapor, pressure, dust, and cloud composition.
- **Laser altimeter** Uses infrared laser pulses to measure distance from spacecraft to surface. With these data, the AI will construct a map of the surface topography.
- **Radio science instrument system** Uses the starship's radio system to probe the gravity field and atmosphere. The AI can translate changes in the radio signals into data about the temperature and pressure within the atmosphere.
- **Thermal emission spectrometer** Takes infrared measurements to determine surface temperature and mineral composition. This instrument also studies atmospheric dust and cloud composition.
- **Radar mapper** With its ability to penetrate thick atmospheres, this instrument provides radar images of the surface topography along with surface emissivity and temperature data.

When the orbital data-gathering phase is completed, you will have detailed information about the new planet's climate; the rocks, soils, and surface features; the location of good landing sites; and the locations of resources for exploitation. The detailed landing Site Map, prepared by the AI after the data analysis, will indicate potential mining locations inferred from surface mineral deposits and topography.

When remote sensing from the starship is completed, you have the option of launching any satellites or probes you may have brought with you. These satellites remain in orbit to perform a continuing function. The geological penetrator probe impacts the surface of the planet to gather more detailed geophysical data than are available from orbit.

Satellite Types

Solar Power Satellite (Powersat)

The function of the powersat, shown in Figure 13-2, is described in Chapter 8. When you pack the starship for your trip, you have up to 10 powersats available. Each powersat has a weight value of 8 and a cost of 15. To be most effective, you need to take two solar power receiver arrays for every powersat you take to the new world.

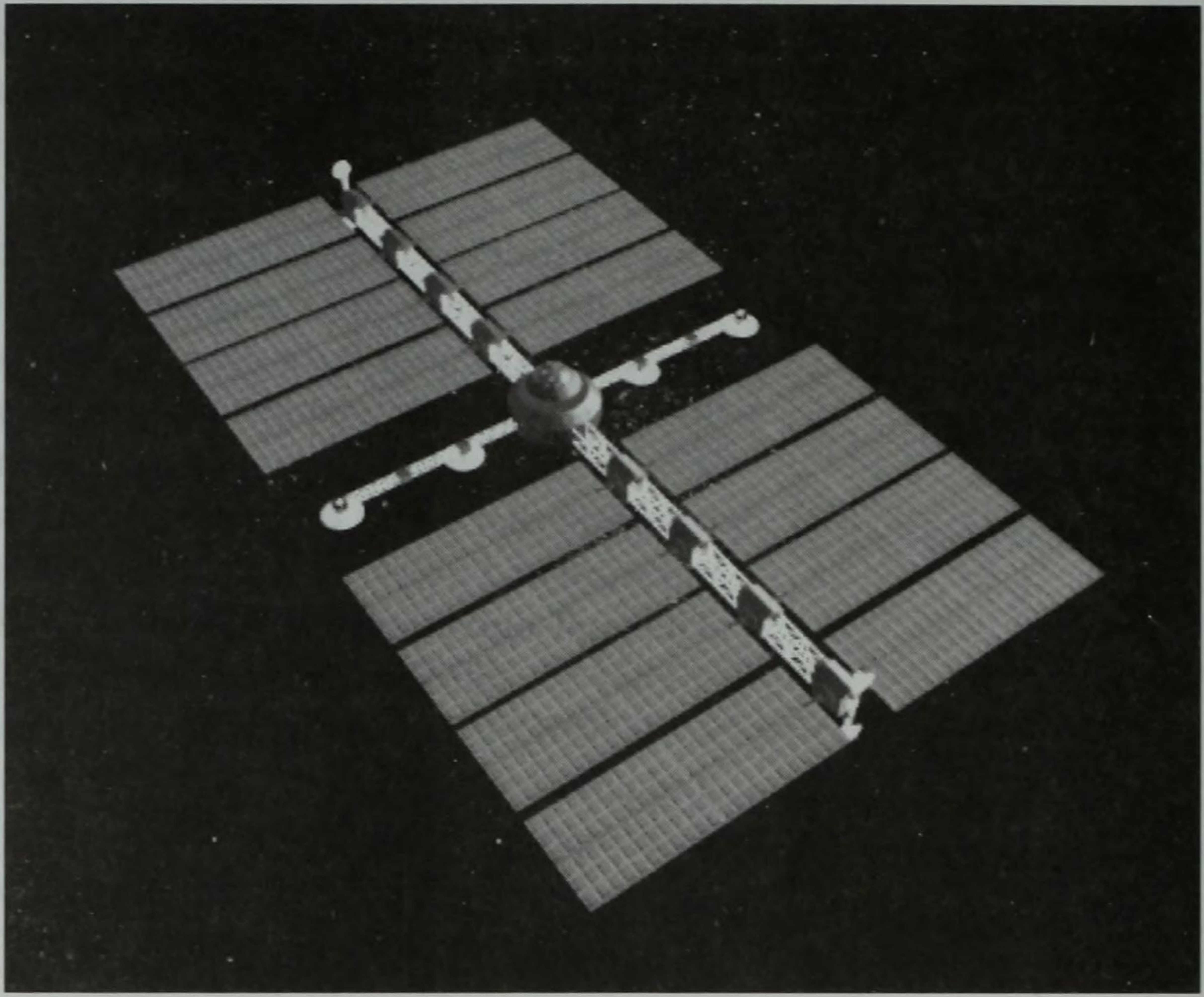


Figure 13-2

Solar powersat

Orbital Observer

The orbital observer, shown in Figure 13-3, contains an imaging system that allows you to keep an eye on planetary activities. If you're so inclined, the artificial intelligence can use these data to watch the development of any opposing colonies that might be located nearby. The term "spy satellite" has such a negative connotation, doesn't it? "Orbital observer" sounds so much friendlier

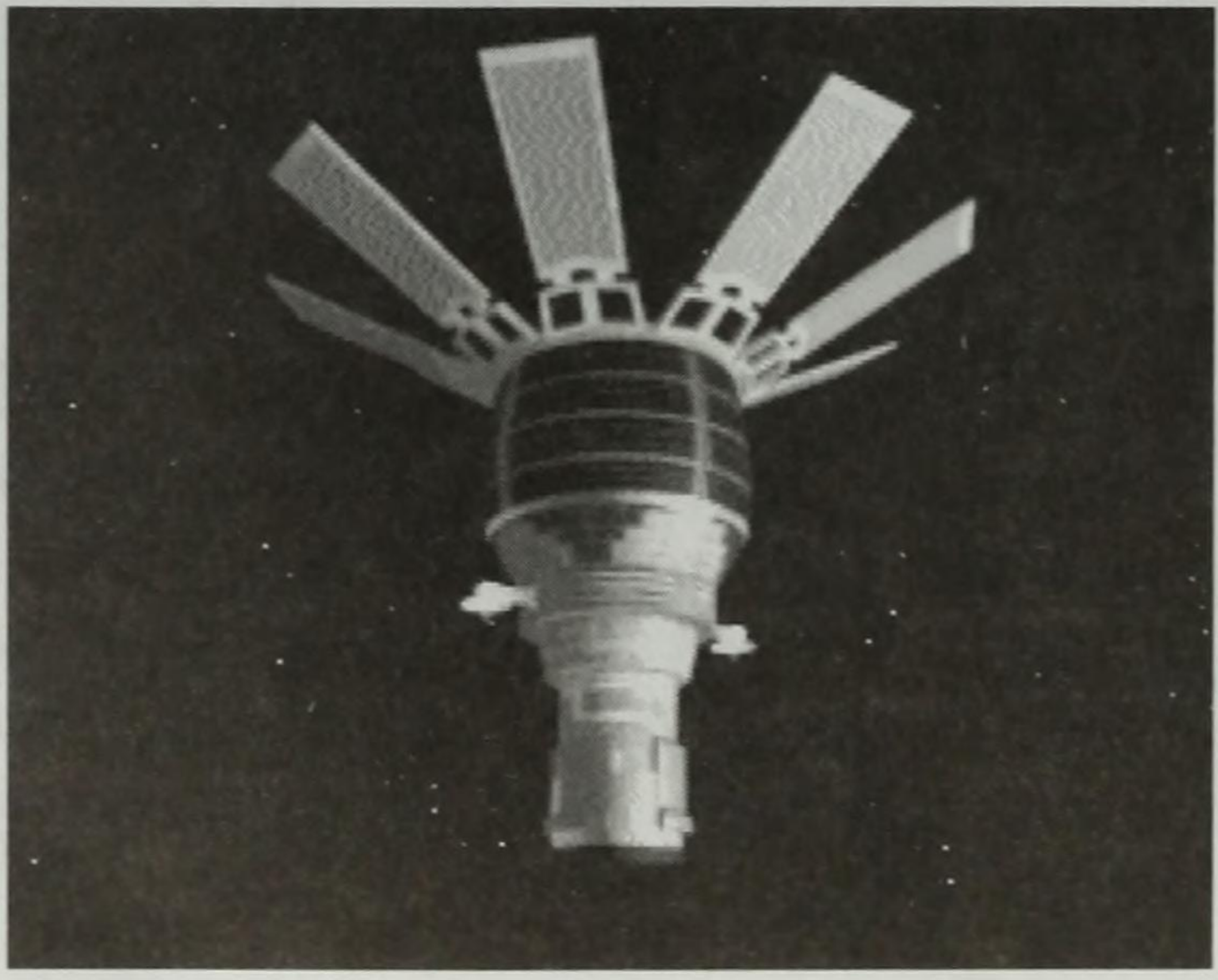


Figure 13-3

Orbital observer

and more scientific. You can purchase up to four of these for your trip. Each observer has a weight value of 6 and a cost of 13.

Weather Satellite (Weathersat)

The primary function of the weathersat on a hostile planet is to give warning of your impending doom. The weathersat can detect solar flares, electrical storms, dust storms, and other annoying meteorological events that can ruin your day. With a weathersat in place, you will often have the opportunity to evacuate your population from the surface and get them underground where they'll be safe. You can purchase up to four of these for your trip to the new world. The weight value of a weathersat is 4 and the cost is 12.

Communications and Navigation Satellite (Comsat)

The comsat improves your communications system and the ability of your robots to find their way around, among other things. In particular, explorer robots navigate to a chosen target with much less difficulty when they have a comsat to pinpoint their positions. Communication with the robot control facility is also much easier when the orbital comsat can receive robot telemetry and transmit it back to your colony. You can purchase up to 10 comsats for full planetary coverage. The weight value of a comsat is 4 and the cost is 11.

Probe Types

Very Long Baseline Interferometer (VLBI)

While you're building your colonization starship, you are provided with a basic set of VLBI probes. These probes, shown in Figure 13-4, provide basic information about four of the potential star systems you might like to colonize. Because they're launched from Earth, there is no weight or cost consideration for VLBIs when you pack your starship. In the time available to you before you launch the starship from Jupiter, the VLBI probes have only enough time to spread out and collect data on the four star systems you've selected. As with radio interferometry, described in Chapter 22, the VLBIs are most effective when they're furthest apart and communicating with each other while pointing at the same target.

Ultra Long Baseline Interferometer (ULBI)

While your colonization starship is being fueled at Jupiter, you can launch any of the ULBI probes you may have purchased.

Figure 13-4

Very long baseline interferometer

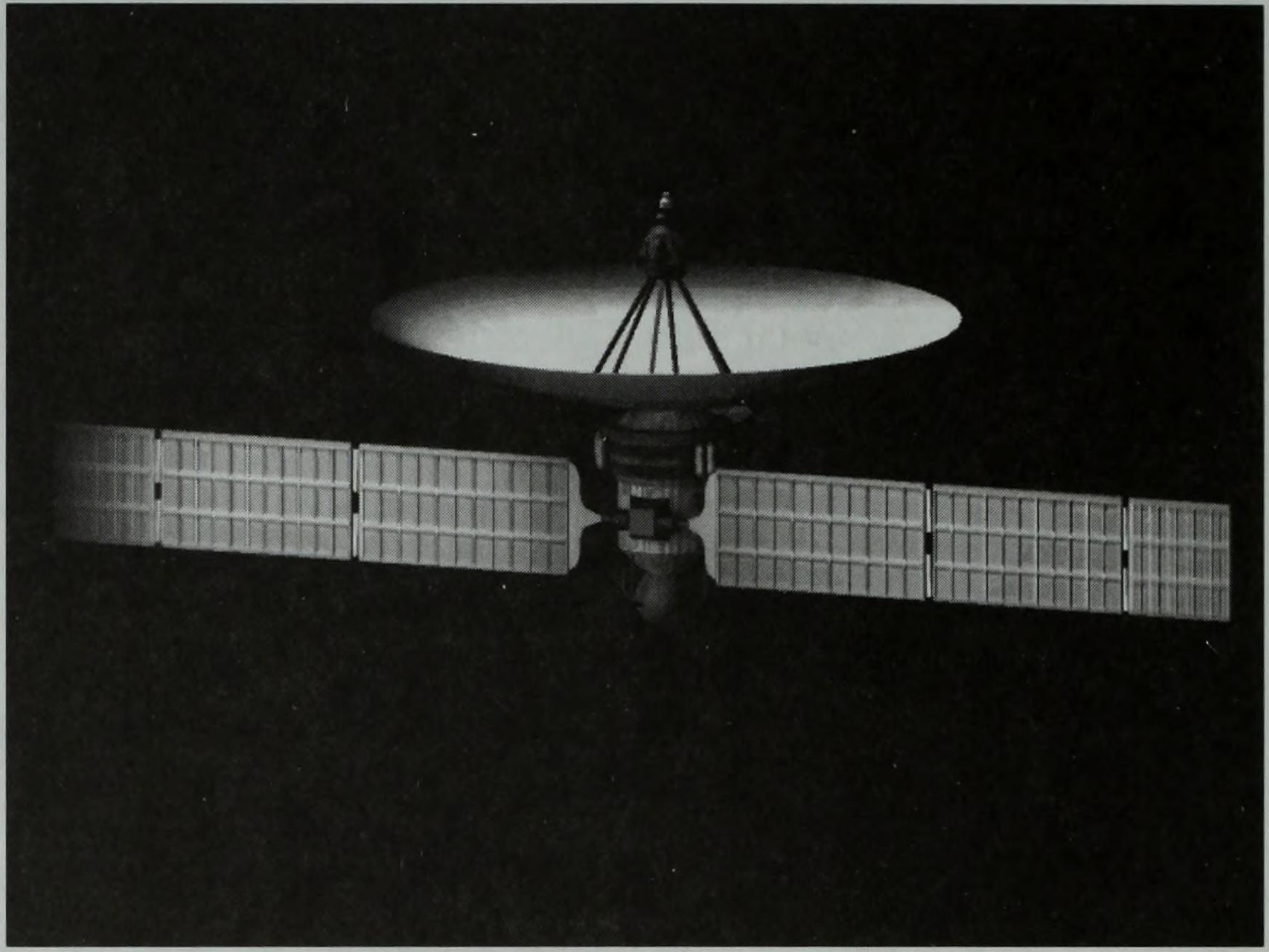


Figure 13-5 shows a ULBI being deployed. Working in unison like the VLBIs, the ULBIs, shown in detail in Figure 13-6, are targeted to collect data on the one star system you've chosen to colonize. These probes are bigger and faster than the VLBIs, and can provide you with higher quality data about the planets in your new star system. In effect, the ULBIs also use the starship as a fifth ULBI, increasing the amount of information they can gather. You can purchase up to four ULBIs. The cost of a ULBI is 14. As you won't be taking the ULBIs on your voyage, there is no weight penalty.

Figure 13-5

ULBI probe being deployed

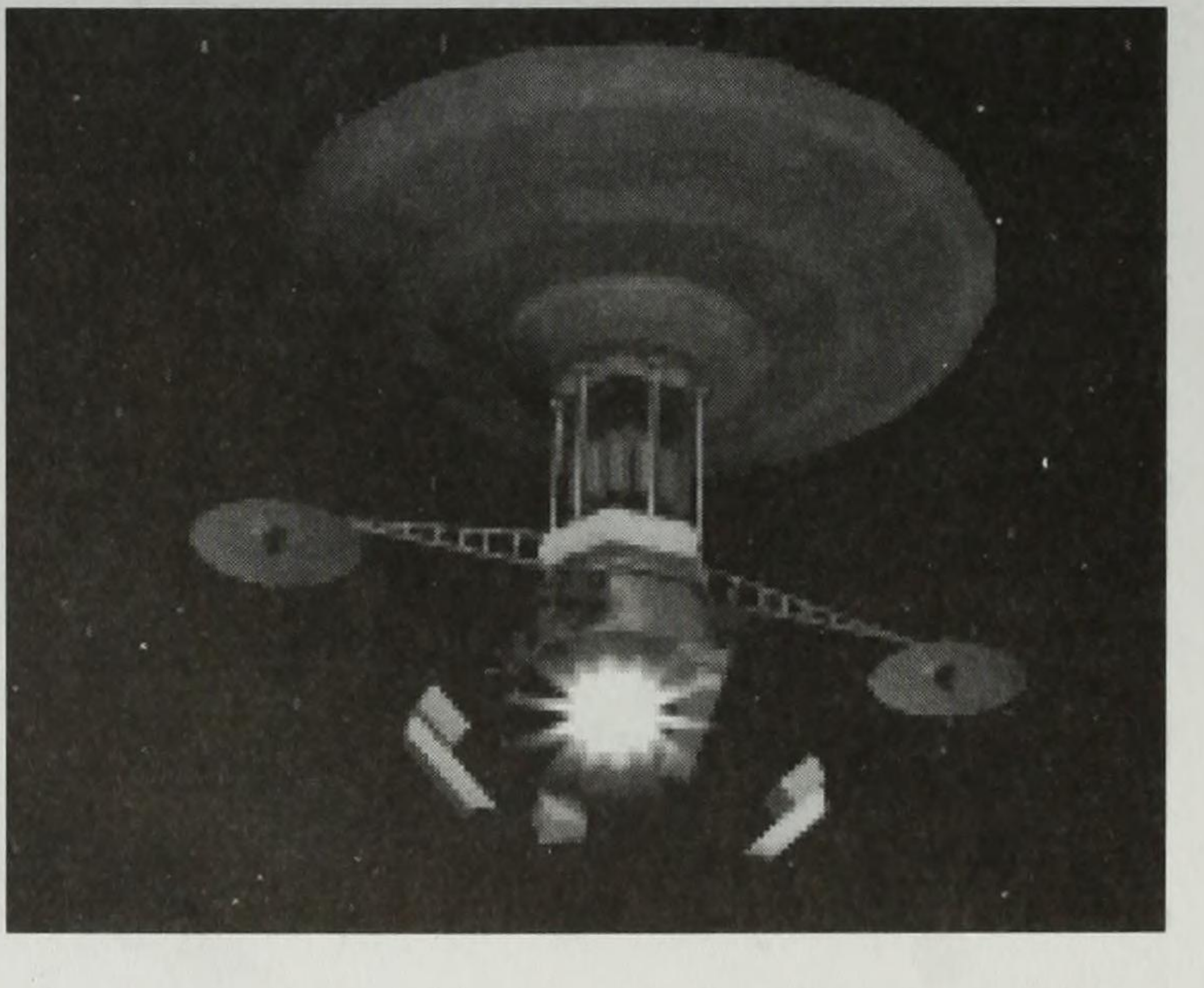
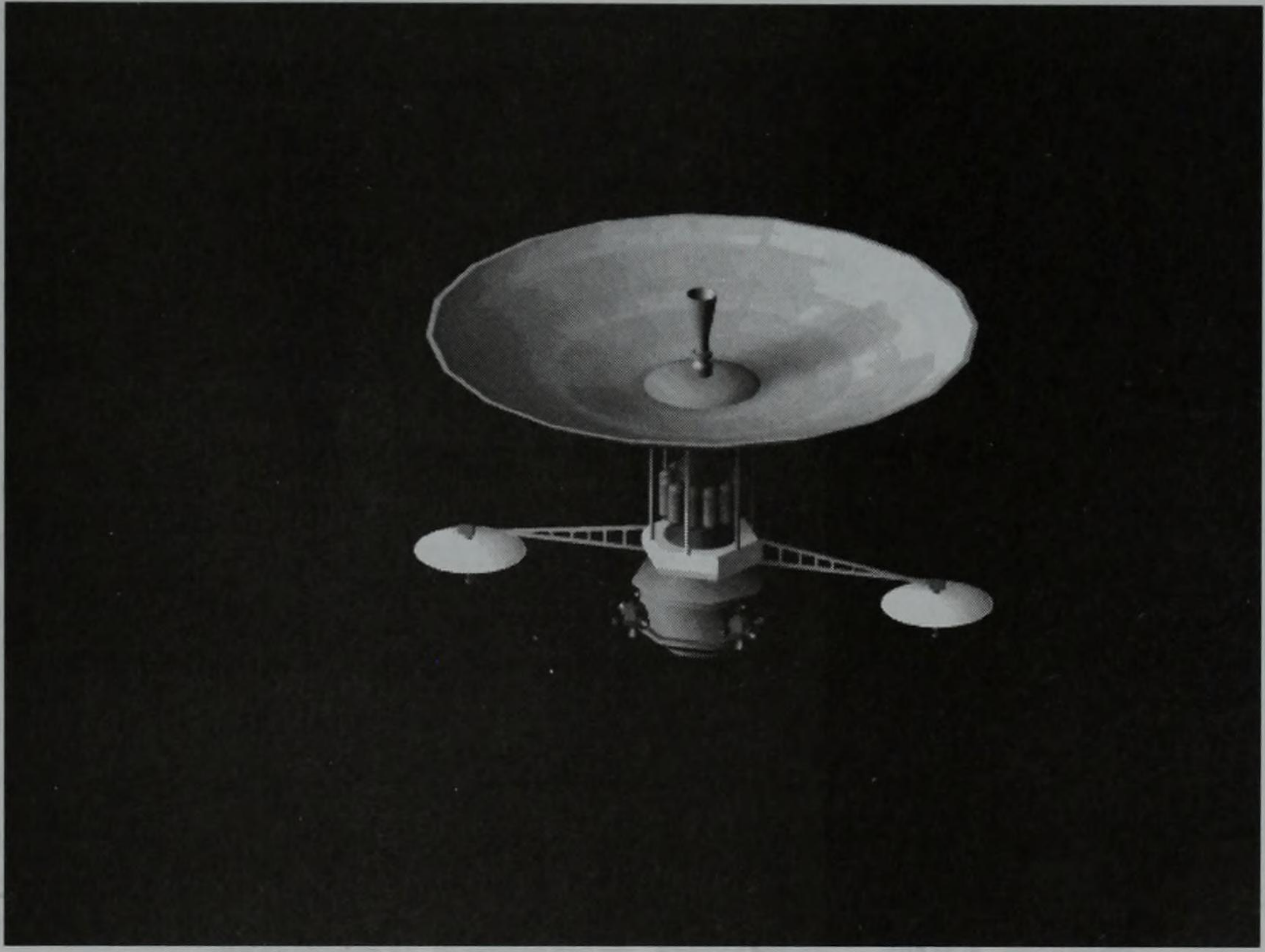


Figure 13-6

Detail of a ULBI

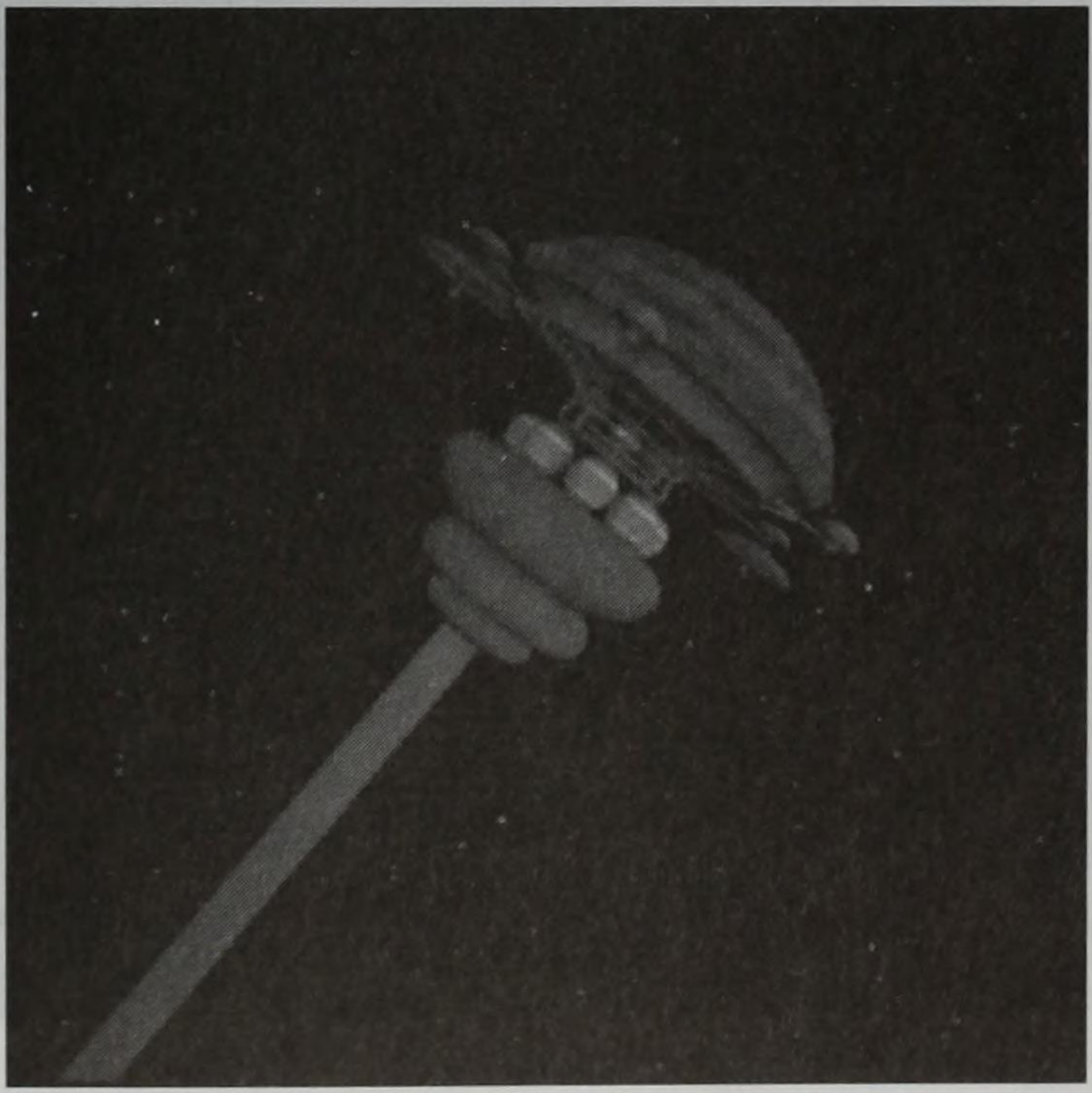


Interstellar Flyby

The interstellar flyby probe, launched while the colonization starship is on its way to the new star system, uses the same sort of propulsion system as the starship and is also fueled at Jupiter. This probe is shown in detail in Figure 13-1. Because the flyby probe, shown in transit in Figure 13-7, has only a tiny amount of payload

Figure 13-7

Flyby probe in transit



in comparison to the starship, it will arrive at your destination long before you do. This probe won't stop, but will pass on through the star system, getting a close-up look at the planets. The information gathered from the flyby will let you make the best choice on which planet to colonize. You can purchase up to two flyby probes. The cost of a flyby probe is 15, which includes the fuel. There is no weight penalty.

Geological Penetrator

The geological surface penetrator, shown in Figure 13-8, is used to gather data directly from the surface of a planet, providing much more detail than is available from orbit. It can determine the major chemical and mineral components in the planetary surface, giving you a better idea of where the most useful resources can be found. You can purchase up to four of these probes. The weight value is 4 and the cost is 14.

Build Your Own Satellite

Meteor Defense Satellite

The meteor defense satellite, shown in Figure 13-9, is a powerful pulsed laser that remains in orbit around your planet to defend your colony from the threat of incoming asteroids and meteors. It

Figure 13-8

Geological penetrator probe being deployed

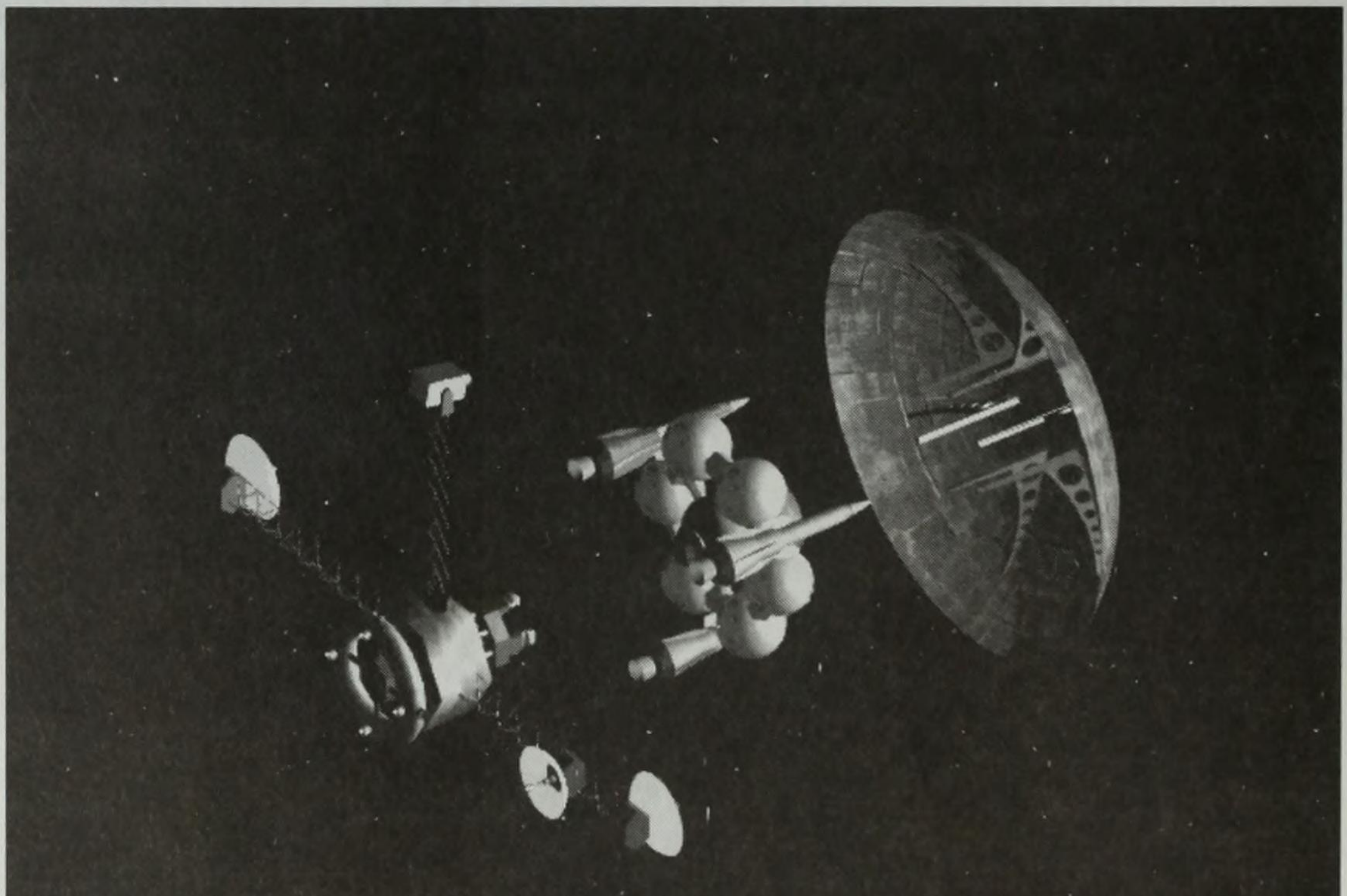
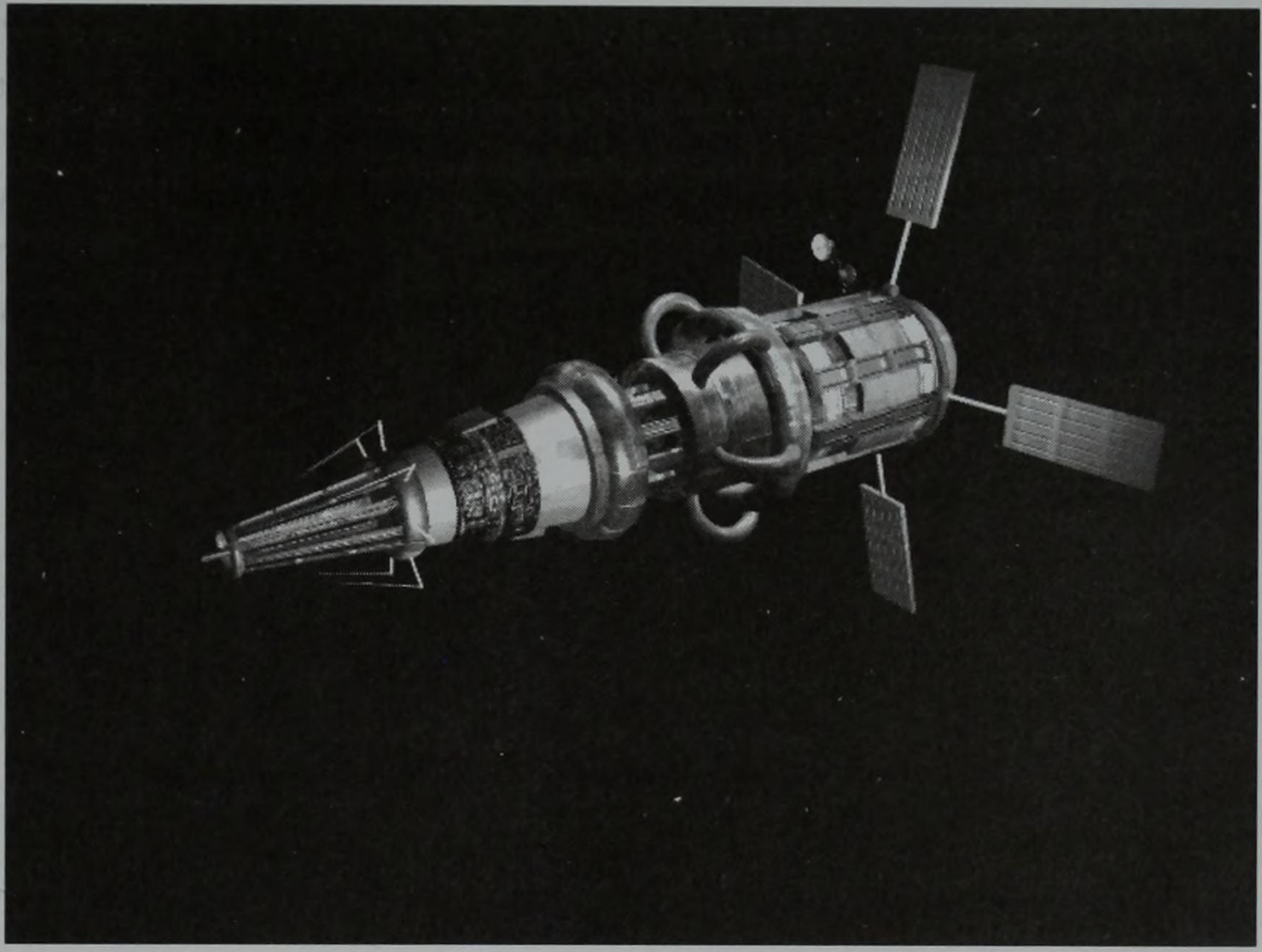


Figure 13-9

Meteor defense satellite

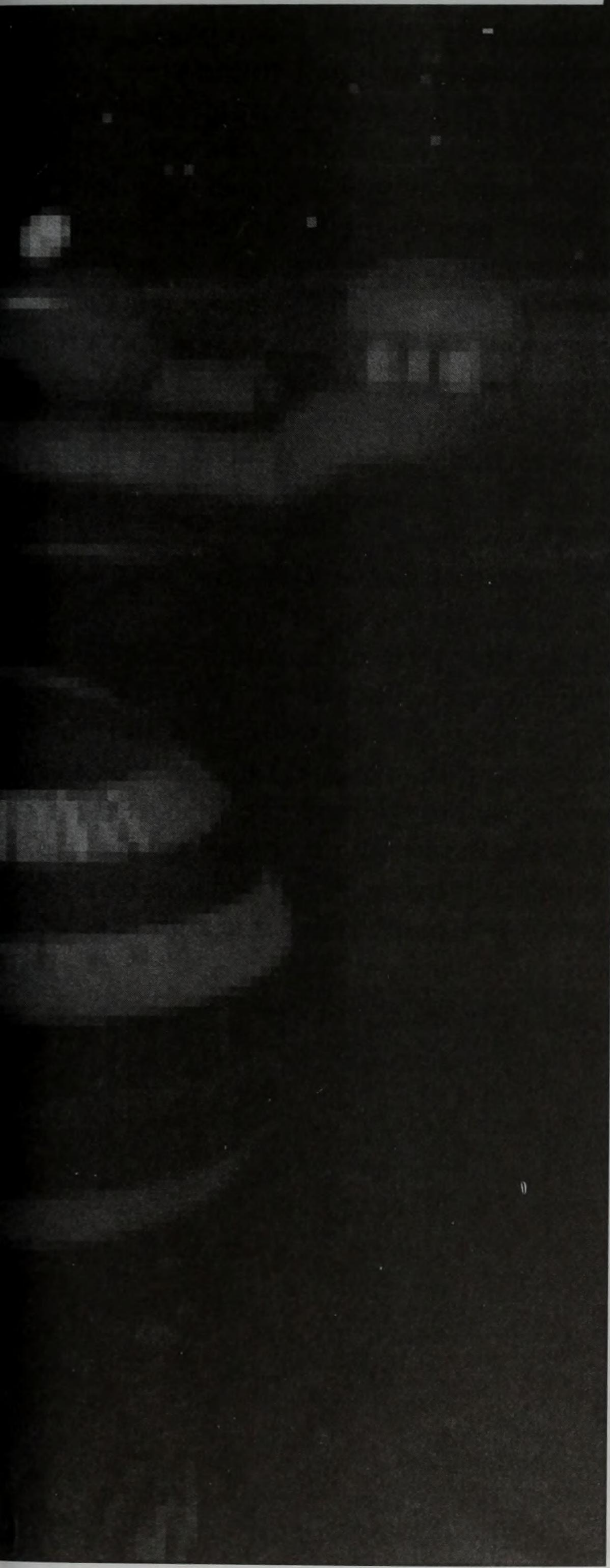


is the only satellite built on and launched from your new planet. Although this satellite would have been handy if it could have been developed on Earth before you left, you must do the research yourself to discover the secrets behind the powerful orbital laser system. After your scientists have finished their research, you must still develop the capability of launching these satellites into orbit around your new planet. It's a good idea to have several of these in orbit as a defensive screen, because most planets have little or no atmosphere to burn up any incoming objects that might damage your colony.

This chapter should have given you some ideas about the tactical use of satellites and probes to gather information for you. Although the starship is equipped with some fine remote sensing equipment, it can't compare to the quality of data provided by the specialized probes. Maintaining your information flow with the satellites will help you manage your colony successfully by increasing the reach of your communications and warning you of nasty surprises. Because the selection of an appropriate planet and a good landing site are so critical to your colony's survival, many of these instruments are designed to provide you with that specific data.

The next chapter delves into research. When you arrive, you've got a shipload of scientists itching to do some work. Although some of them will have to build the colony structures, others can be assigned research tasks to improve everyone's quality of life. If you're trying to establish a foothold on a particularly hostile world, research may be your only means of discovering how to survive.

Figure 14-1 Dangerous research is performed at the Hot Laboratory.



14

If a Research Tree Falls in the Forest, Can Anyone Hear It?

I believe most simply in the nobility of this great effort to understand nature, and what we can of ourselves. That is science.

J. Robert Oppenheimer

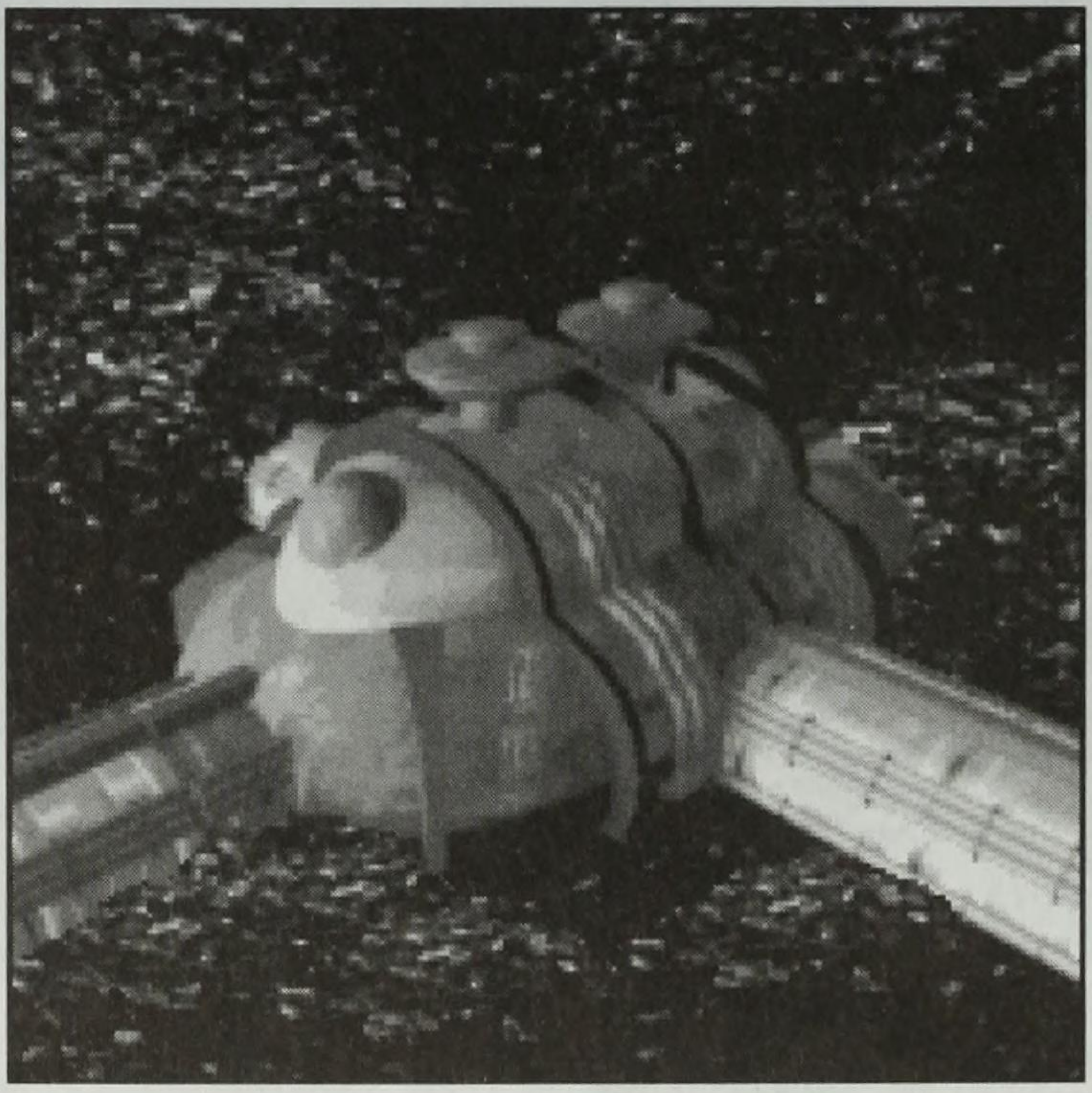
Scientific research is the key to your continued survival and the advancement of your civilization. When you land on your new planet, you have a shipload of scientists who haven't done any work for decades, so they're itching to use their brains and produce results for you. In the beginning, you'll probably be using them to get your colony structures built, but they'll be happier once you put them to work in your laboratories.

This chapter shows you the secrets of scientific research in *Outpost*. If you want the process to remain a mystery, don't read any further. I'll be showing you how Basic Research speeds progress toward all your current research goals, the amount of time required to complete each line of research, the effect of applying an artificial intelligence to lab work, and the factors that have a direct impact on the rate of scientific progress.

By clicking on an active laboratory, shown in Figure 14-2, you have access to the individual lab report. This lab report, described in detail in Chapter 5, gives you a quick update on that lab, any operating problems it might have, and its current line of research. From this report, you also have access to the research tree so that you can tell this lab which subject they should be investigating. Any progress your scientists may have made on their current research topic is roughly indicated by the number of lab rats in this display. Because scientific research does not produce results at a specific time, the lab rats can be only a rough indicator of how

Figure 14-2

Laboratory



much progress has been made. Later in this chapter, you'll find the basic number of turns required in *Outpost* to achieve discoveries in each research area.

The individual lab report will also tell you the status of the current research being performed by that lab. The four conditions are: Inactive, In Progress, On Hold, Complete. "Inactive" indicates that the lab does not currently have enough resources, or scientists, to perform research. "In Progress" means they're working on your selected research topic. "On Hold" means that you have paused their research as if you've sent them on vacation, so nothing will be lost in terms of their progress. "Complete" means their current line of research has been completed and they're waiting to be reassigned to something new.

Basic Research: An Investment in Your Future

Basic Research is designed to function as a "think tank," where some of your scientists have been placed in a laboratory and told that they can research whatever subject catches their interest. Some of the more famous think tanks on Earth are the RAND Corportion, Bell Laboratories, and SRI International. These research institutes exist to solve complex problems, with the help of high-powered scientists. In *Outpost*, an active program of Basic Research will generate beneficial results for your entire research effort. About every 100 turns, progress on all current research will accelerate by 5 turns, but the minimum time required to complete any line of research will still remain at 25 turns. So, if you have 30 turns remaining before you discover your first terraforming microbe, and 100 turns of active Basic Research have been completed, then you'll only need 25 more turns to make your discovery.

Rules Affecting Basic Research

Three main rules affect scientific progress through Basic Research:

1. The "basic" number of turns for completing a Basic Research phase is 100, plus or minus 15 turns.
2. An artificial intelligence can be applied to a lab working on Basic Research, but it will have no effect on the rate of research progress. This type of "think tank" work is too abstract to be aided by an artificial intelligence at this level of thought.
3. The basic number of turns for Basic or Applied Research progress is modified by Morale according to the following formulas:

- Research progress is cut by 50 percent if Morale equals 0 to 249.
- Research progress is cut by 25 percent if Morale equals 250 to 449.
- Research progress is unaffected if Morale equals 450 to 549.
- Research progress is increased by 25 percent if Morale equals 550 to 749.
- Research progress is increased by 50 percent if Morale equals 750 to 1000.

(Note: When the game begins, the Morale value is set at 600.)

These are the formulas used to affect research progress in the game. Because the specific Morale values are used only by the program internally and are not visible to the player, you can estimate the current level of Morale only from the Executive Summary Report.

Applied Research: When You Know What You Want

The root of the main research tree is Applied Research. Figure 14-3 shows a portion of the research tree. Within this broad category, general research topics can be studied to generate new and more specific research topics. When a line of research has been followed through an entire branch of the tree, the final result can be a new structure for your colony, such as a terraforming facility; a beneficial modifier that directly affects Morale or Trade; a system improvement such as Communications; an improved method of food production; an increase in the technological level of your entire civilization; or the ability to build and launch new satellites. Specific end results are listed at the end of this chapter.

This research tree is not meant to represent every category of human thought. It is condensed down to the major research topics deemed necessary to the advancement of your space colonization effort. It may seem that many of these categories must have already been mastered so that your starship could have arrived at your new planet. However, you loaded the starship with only the basic necessities for survival. The technology for building new satellites, for example, must be reestablished on your new colony, using local resources and the factories you build yourself. Although subjects such as astrophysics were heavily researched on Earth, they must now be studied from an entirely new location. You have the knowledge that you and your scientists brought from Earth, and this works to your advantage, but new methods and resources must be used now that you're on a different planet.

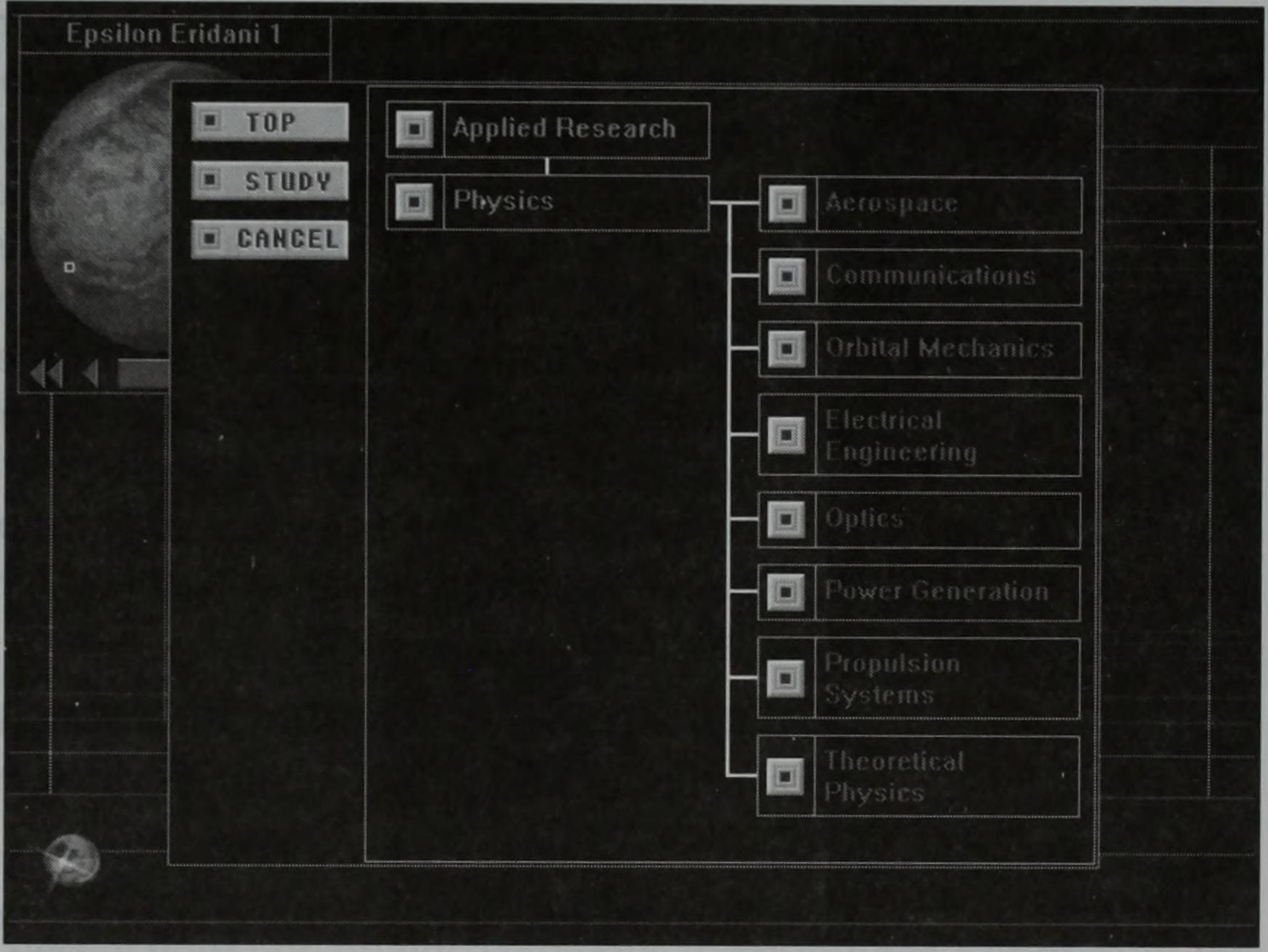

Epsilon Eridani 1
▣ TOP
▣ STUDY
▣ CANCEL
▣ Applied Research
▣ Physics
▣ Aerospace
▣ Communications
▣ Orbital Mechanics
▣ Electrical Engineering
▣ Optics
▣ Power Generation
▣ Propulsion Systems
▣ Theoretical Physics

Figure 14-3

Physics branch of research tree

The main research categories are as follows:

Astronomy The science that deals with the celestial bodies—their descriptions, radiations, movements, structures, physical and chemical characteristics, origin, evolution, and arrangement. This includes astrophysics, basic astronomy, planetary astronomy, and stellar astronomy.

Biology The science of living matter in all its forms and phenomena. This includes medicine, pharmacology, genetics, exobiology, agriculture, physiology, and ecology.

Chemistry The science that deals with the composition, properties, and transformations of substances and various elementary forms of matter. This includes biochemistry, metallurgy, and quantum chemistry.

Planetary sciences The sciences that deal with the physical and environmental aspects of planets. This includes meteorology, geography, geology, mining, and engineering geology.

Mathematics The systematic treatment of magnitude, relationships between figures and forms, and relations between quantities expressed symbolically. Results from mathematics research apply to many other research topics.

Computer science The study of computers, information, programming, and algorithms. This includes artificial intelligence and systems analysis.

Physics The science that deals with matter, energy, motion, and force. This includes communications, orbital mechanics, electrical engineering, optics, power generation, propulsion systems, quantum mechanics, and nanotechnology.

Social sciences The science that deals with the institutions and functioning of human society and with the interpersonal relationships of individuals as members of society. This includes economics, political science, psychology, sociology, urban studies, and police science.

Humanities The branches of learning having primarily a cultural character, such as art, music, philosophy, history, and literature.

Rules Affecting Applied Research

Four main rules affect scientific progress through Applied Research:

1. The starting value for the progress calculation is the "basic" value listed after each topic below.
2. The "basic" number of turns for completing research on an Applied Research topic can be 25, 50, 75, 100, or 200, with a random variation plus or minus 10 turns.
3. This basic amount of required research time is modified by Morale, using the formulas listed in Basic Research rule 3 above.
4. An artificial intelligence (AI) without personality problems, who is assigned to a lab doing Applied Research, will benefit research progress at that lab. Each time a new research topic is assigned to a lab, and an AI is present or assigned to that lab, the AI will randomly affect the rate of progress. An AI can reduce, from 0 to 10 percent, the number of turns required to complete research. If the AI is removed from that research, then reassigned to the same research after one or more turns, this percentage of its effect is regenerated for a new value in the same range from 0 to 10 on the remaining turns.

Research Topics

ASTRONOMY—Astrophysics
50 turns required

Astrophysics is the field of astronomy concerned with the physical, chemical, and thermal properties of celestial bodies accessible to direct observation and also inferred from theory. Research in this area results in the celestial navigation abilities required to build your new space program.

ASTRONOMY—Basic Astronomy
25 turns required
Basic astronomical research from your new planet results in awareness of your surroundings. Specifically, this will give you warning of any incoming meteor showers.

ASTRONOMY—Planetary Astronomy
50 turns required
Planetary astronomy from your new colony results in data gathered about the other local planets in that star system without the use of planetary probes.

ASTRONOMY—Stellar Astronomy
25 turns required
Stellar astronomy from your new planet results in more awareness of your potentially dangerous surroundings. Specifically, this will give you warning of extra activity on your local star and the likelihood of any incoming solar flares.

BIOLOGY—Medicine
50 turns required
Research in basic medicine results in the discovery of new methods for long-term suspended animation. This is true suspended animation, not the "slow sleep" decreased metabolic state in which your colonists traveled aboard the starship. Research in basic medicine is also required for research in pharmacology and genetics.

BIOLOGY—Medicine—Pharmacology
25 turns required
Research in pharmacology, the science of drugs, will improve the general health of your population. Research in this area is also required to reach alien pharmacology.

BIOLOGY—Medicine—Pharmacology—Alien Pharmacology
75 turns required
Research in alien pharmacology, the science of drugs developed through resources native to your new planet, allows you to develop the alien virus cure.

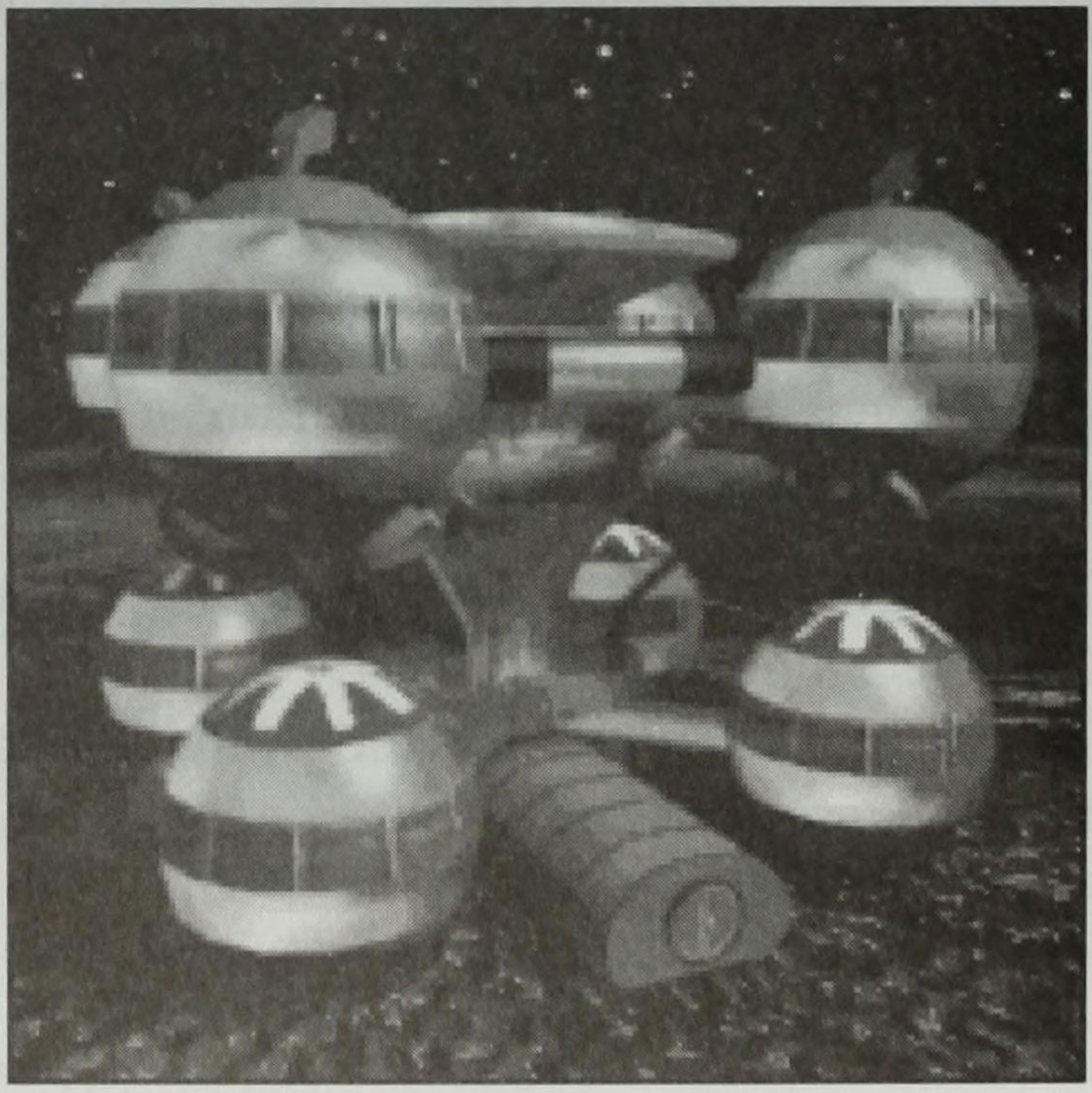
BIOLOGY—Medicine—Genetics
25 turns required
Research in basic genetics, which deals with the heredity and variation of organisms, relates to the study of genetic changes that may have been induced in the population during starflight or while living on the new planet. Research in this area is required to reach genetic engineering.

BIOLOGY—Medicine—Genetics—Genetic Engineering
100 turns required
Research in genetic engineering, which deals with the direct manipulation of genetic materials to produce a desired variation in an organism, results in life extension for your population and a microbe that is ideally suited to terraforming your new planet. Research in this area is also required to reach agriculture 2. Genetic engineering is studied in the surface "hot" (hazardous) research lab shown in Figure 14-4.

BIOLOGY—Medicine—Genetics—Genetic Engineering—Agriculture 2
100 turns required
Research in agriculture 2, which deals with the genetic manipulation of food grains, results in improved food production levels and a new food source that is ideally suited to the conditions on your new planet.

Figure 14-4

Hot lab



BIOLOGY—Exobiology
200 turns required
Research in exobiology, which deals with extraterrestrial biology on your new planet and includes research in alien genetics, results in a new food source based on local resources that is ideally suited to the conditions on your new planet. A microbe for terraforming your planet is another result of this research.

BIOLOGY—Plant Biology (Botany)
25 turns required
Research in plant biology deals with adapting the plants imported from Earth to grow better on your new planet. Research in this area is required to reach agriculture 1.

BIOLOGY—Plant Biology—Agriculture 1
200 turns required
Research in agriculture 1, which specifically deals with the growing of imported Earth plants in the local conditions of your new planet, results in improved food production through new growing methods, and in a new food source developed as a mutant strain of green algae that thrives on cosmic radiation. This new strain of algae is popularly called "soylent green."

BIOLOGY—Physiology
25 turns required
Research in basic physiology deals with the effects of starflight and increased levels of cosmic radiation on the human body. Research in this area is required to reach anatomy and comparative physiology.

BIOLOGY—Physiology—Anatomy
25 turns required
Research in anatomy deals with the effects of starflight and the local environment on the human body. This research results in a general health improvement for your population.

BIOLOGY—Physiology—Comparative Physiology
25 turns required
Research in comparative physiology deals with the long-term effects of living in the local environment, including changes in the human body resulting from weaker or stronger gravities as compared to Earth, and from cosmic radiation. This research results in a general health improvement for your population.

BIOLOGY—Embryology
50 turns required
Research in embryology, which deals with the development and formation of human embryos, results in a higher infant survival rate among your population.

BIOLOGY—Immunology
25 turns required
Research in immunology, which deals with methods of resisting disease or reducing the effects of disease, results in a general health improvement for your population.

BIOLOGY—Entomology
50 turns required
Research in entomology, a branch of zoology that deals with insects, results in knowledge that can be applied to the construction of very small robots, known as microbots, after research into robotics 1 has also been completed.

BIOLOGY—Ecology
25 turns required
Research in ecology, which deals with the interrelationship of organisms and their environments, specifically your colonists in relation to their new planetary environment, is necessary to establish the basis for research in alien ecology.

BIOLOGY—Ecology—Alien
25 turns required
Research in alien ecology is a thorough study of your new planet and its environment. This research is required as a basis for specific studies into the atmospheric, terrestrial, and marine components of the alien ecology.

BIOLOGY—Ecology—Alien—Atmospheric
75 turns required
Research in atmospheric alien ecology is the specific study of the atmosphere, if any, and its interactions with your new planet. Research in this area is necessary for completing studies leading to terraforming, as well as providing more information for local meteorology.

BIOLOGY—Ecology—Alien—Terrestrial
75 turns required
Research in terrestrial alien ecology is the specific study of the physical characteristics of your new planet and its interactions with the rest of the environment. Research in this area is necessary for completing studies leading to terraforming, as well as providing more information for local meteorology.

BIOLOGY—Ecology—Alien—Marine
100 turns required
Research in marine alien ecology is the specific study of the marine environment, if any, of your new planet and its interaction with the rest of the biosphere. Research in this area is necessary for completing studies leading to terraforming, as well as providing more information for local meteorology.

CHEMISTRY—Biochemistry
25 turns required
Research in the biochemistry of the local environment is required as a basis for further study into the development of nanotechnology.

CHEMISTRY—Physical Chemistry
25 turns required
Research in physical chemistry and the way it operates in the local environment is required for further research into metallurgy and materials processing.

CHEMISTRY—Physical Chemistry—Metallurgy
25 turns required
Research into metallurgy, the science and technology of metals and how they react to the environment of your new planet, results in the metalworking knowledge required to build a monorail system.

CHEMISTRY—Physical Chemistry—Materials Processing
50 turns required
Research into materials processing, the study of how materials react to the environment of your new planet, results in improved methods for processing mined ore through your smelter.

CHEMISTRY—Quantum Chemistry
100 turns required
Research into quantum chemistry, the molecular manipulation of chemical compounds, is one of the basic areas of research required for the development of nanotechnology robots.

PLANETARY SCIENCES—Meteorology
100 turns required
Research into the meteorology of your new planet results in the ability to predict the weather, or at least to predict planetary-scale meteorological events, such as dust storms. Research in this area is also a basic requirement for the development of terraforming.

PLANETARY SCIENCES—Geography
50 turns required
Research in geography is an aid in mapping the area surrounding your colony, which helps robot navigation.

PLANETARY SCIENCES—Geology
25 turns required
Research in geology, which deals with the history, development, and current physical state of your new planet, is required as a basis for further research into terrestrial geology, mineral resources, and engineering geology.

PLANETARY SCIENCES—Geology—Terrestrial Geology
25 turns required
Research in terrestrial geology, a more thorough study of the development and current physical state of the surface and underground features of your new planet, is required for further research into earthquakes, mineralogy, and volcanoes.

PLANETARY SCIENCES—Geology—Terrestrial Geology—Tectonics and Earthquakes
50 turns required
Research into tectonics and earthquakes on your new planet results in the ability to predict earthquakes, if your new planet is geologically active.

PLANETARY SCIENCES—Geology—Terrestrial Geology—Mineralogy
100 turns required
Research into mineralogy helps you develop your mines faster and process the ores more efficiently.

PLANETARY SCIENCES—Geology—Terrestrial Geology—Vulcanology
50 turns required
Research into vulcanology, the study of volcanoes, results in the ability to predict volcanic eruptions, if there are any on your new planet. Study in this area can also give you clues regarding possible geothermal energy sources underground.

PLANETARY SCIENCES—Geology—Mineral Resources
50 turns required
Research in mineral resources and their distribution on your new planet is necessary for further research into terrestrial mining and extraterrestrial mining.

PLANETARY SCIENCES—Geology—Mineral Resources—Terrestrial Mining
100 turns required
Research in terrestrial mining leads to improved mine production.

PLANETARY SCIENCES—Geology—Mineral Resources—Extraterrestrial Mining
100 turns required
Research in extraterrestrial mining, which makes use of local resources that are not on your new planet, such as asteroids, is required for the development of your new space program.

PLANETARY SCIENCES—Geology—Engineering Geology (Structural)
50 turns required
Research into engineering geology as it relates to your new planet results in more efficient road building and bulldozing.

MATHEMATICS
100 turns required
Research into mathematics is required as a basis for the development of several technologies. In combination with other research areas, mathematical research leads to the new space program, efficiency improvement for your factories, and the mass driver.

COMPUTER SCIENCE—Artificial Intelligence
25 turns required
Basic artificial intelligence research is necessary for further study to create AI managers, nanotechnology, space probe intelligence, robotics, advanced processors, and systems analysis.

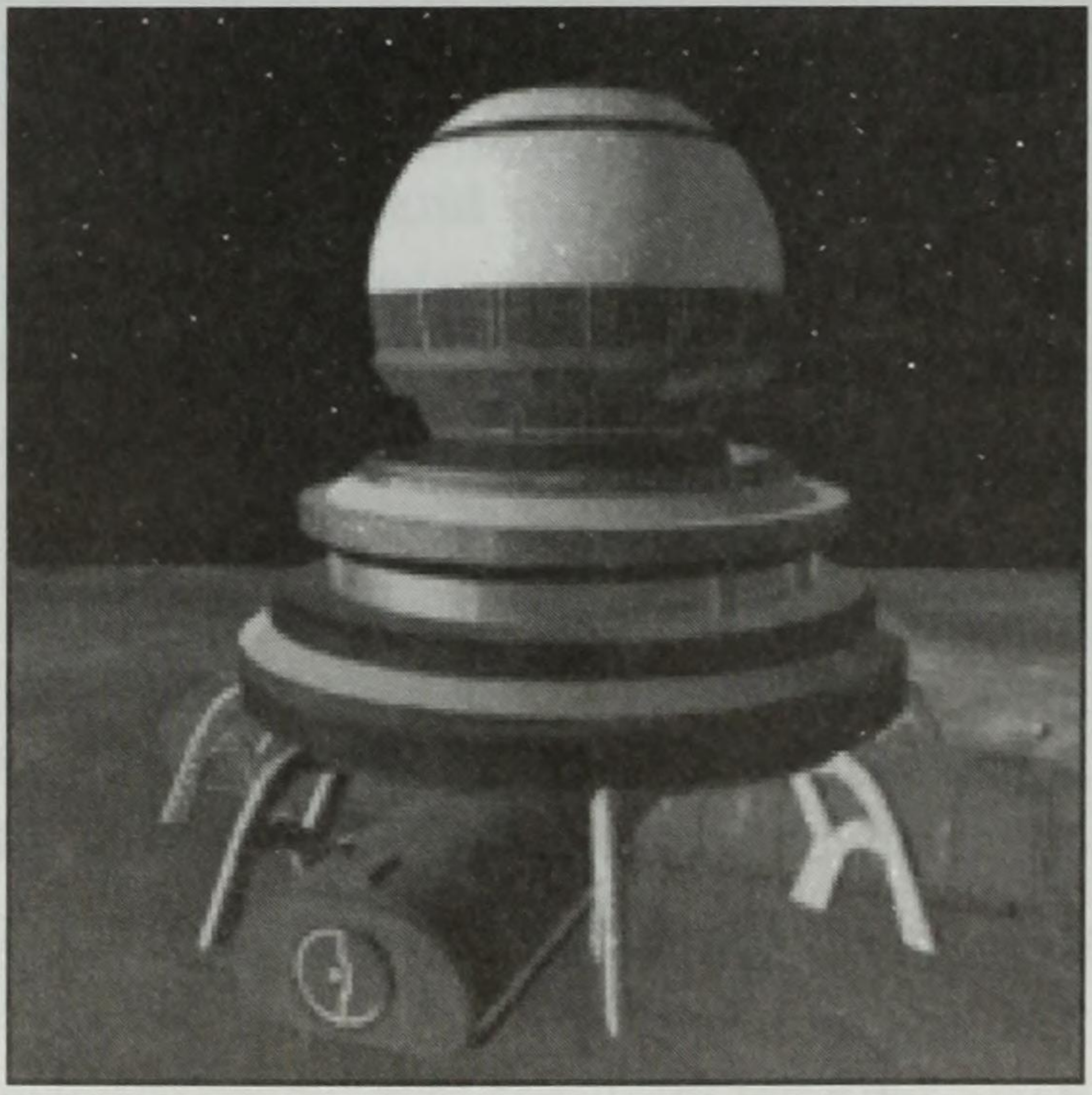
COMPUTER SCIENCE—Artificial Intelligence—AI Managers
100 turns required
Research into AI managers, combined with research into advanced processors, gives you multiple AI personalities that can be assigned to various management and research tasks.

COMPUTER SCIENCE—Artificial Intelligence—
AI Personality Problems
50 turns required
Research into AI personality problems will solve any problems you might have with the multiple AI personalities. In the early stages of multiple AI development, personality quirks can cause your AIs to behave unpredictably. This research is basically psychotherapy for AIs.

COMPUTER SCIENCE—Artificial Intelligence—
Nanotech-nology 1
100 turns required
Research into nanotechnology 1, which deals with the artificial intelligence of the automated life forms you'll be developing in the future, is one of the components you'll need to develop full nanotechnology capability. This subject is studied in the nanotechnology lab shown in Figure 14-5.

Figure 14-5

Nanotechnology laboratory



COMPUTER SCIENCE—Artificial Intelligence—
Space Probe Intelligence
100 turns required
Research into space probe intelligence allows for the future development of interplanetary probes with enough on-board intelligence to study interesting features of other planets.

COMPUTER SCIENCE—Artificial Intelligence—Robotics 1
75 turns required
Research into robotics 1 is a basic requirement for further study leading to a variety of advanced robots. Combined with robotics 2, a subcategory of physics, this leads to research on airbots, repairbots, and human worker replacements.

COMPUTER SCIENCE—Artificial Intelligence—Robotics 1—
Airbots
100 turns required
Research in this area leads to the development of rocket-propelled robots (airbots).

COMPUTER SCIENCE—Artificial Intelligence—Robotics 1—
Repairbots
100 turns required
Research into this area leads to the development of robots that are able to locate and repair damaged robots that have been lost in the field.

COMPUTER SCIENCE—Artificial Intelligence—Robotics 1—
Humanoid Workers
200 turns required
Research in this area leads to the highly sophisticated humanoid worker replacements that can assume the physical labors of human workers and perform 24 hours a day, freeing the humans for other activities, such as scientific research. This improves human morale in the colony.

COMPUTER SCIENCE—Advanced Processors
50 turns required
Research into advanced processors, in combination with research into AI managers, gives you multiple AI personalities that can be assigned to various management and research tasks.

COMPUTER SCIENCE—Systems Analysis
25 turns required
Research into systems analysis is a basic requirement to establish more efficient systems in your colony. This is necessary for further research into efficiency studies.

COMPUTER SCIENCE—Systems Analysis—Efficiency Studies 1
50 turns required
Research into efficiency studies 1, a thorough examination of existing methods of factory production and management on your colony, leads to improved factory efficiency and production.

COMPUTER SCIENCE—Systems Analysis—Efficiency Studies 2
100 turns required
Research into efficiency studies 2, a thorough examination of existing methods of doing things throughout your colony, leads to so much efficiency that your entire civilization qualifies for an advance in their overall technological level.

PHYSICS—Aerospace
25 turns required
Research into aerospace is the foundation for further study into wind tunnels, spacecraft testing and analysis, orbital space stations, and satellites and probes.

PHYSICS—Aerospace—Wind Tunnels
25 turns required
Research into wind tunnels is one of the subjects required for developing your new space program.

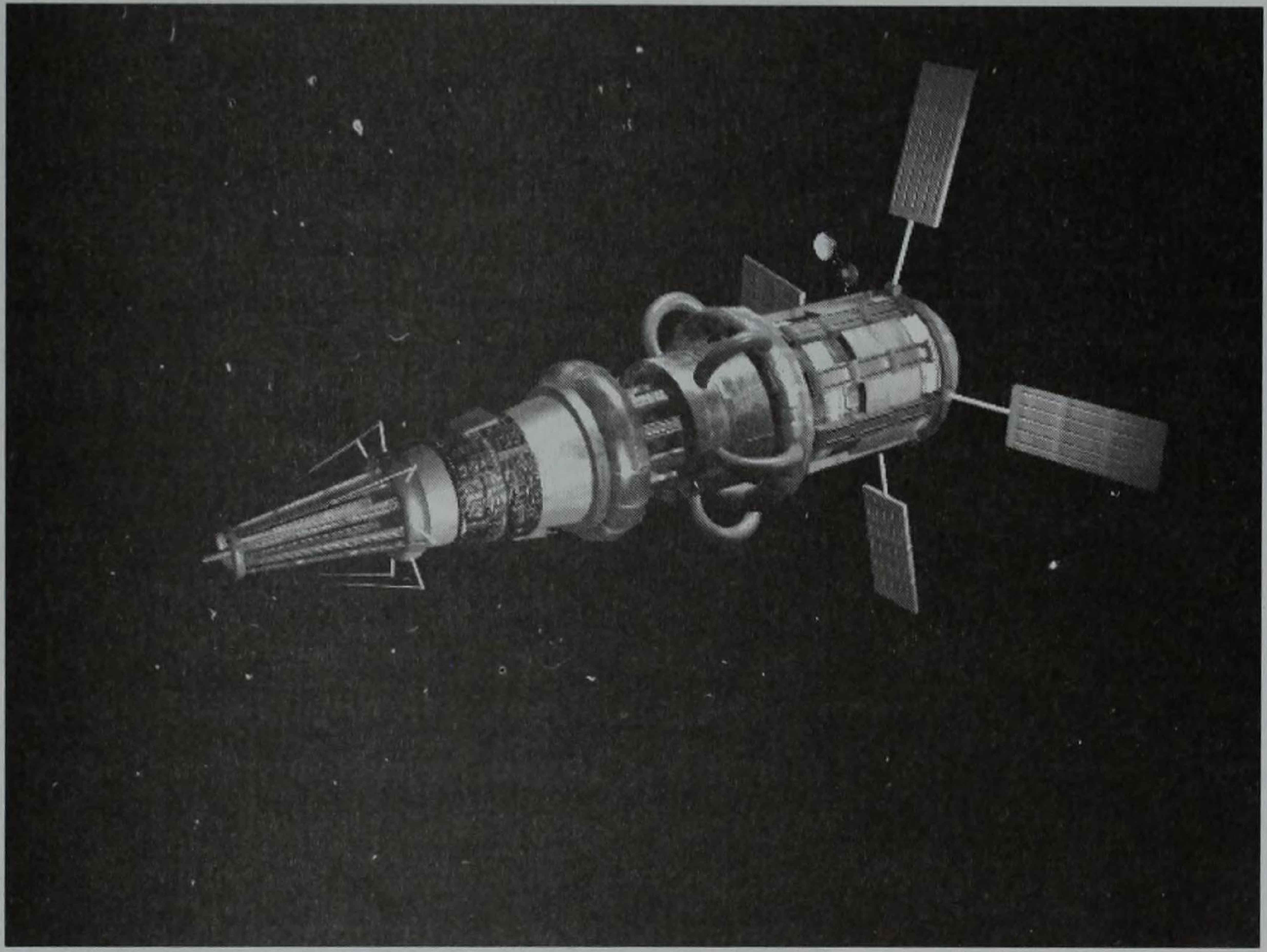
PHYSICS—Aerospace—Spacecraft Testing and Analysis
25 turns required
Research into spacecraft testing and analysis is one of the subjects required for developing your new space program.

PHYSICS—Aerospace—Orbital Space Stations
50 turns required
Research into orbital space stations as they apply to your new planet results in the design of a new space lab and space dock for building spacecraft once your space program is active.

PHYSICS—Aerospace—Satellites and Probes
25 turns required

Figure 14-6

Meteor defense satellite



When combined with optics research, study in this area generates several new satellite and probe proposals for further study, including the meteor defense satellite, communications and navigation satellite (comsat), solar power satellite (powersat), geological penetrator probe, orbital observer, weather satellite (weathersat), interstellar flyby probe, and ultra long baseline interferometer (ULBI) probe.

PHYSICS—Aerospace—Satellites and Probes—Meteorsat
100 turns required
Research into the meteor defense satellite (meteorsat) leads to the development of this reuseable meteor defense. Once the space program is operating, a heavy lifter can launch this and other satellites into orbit. A meteorsat is shown in Figure 14-6.

PHYSICS—Aerospace—Satellites and Probes—Comsat
100 turns required
Research into the comsat leads to the development of this orbital communications and robot navigation satellite. Once the space program is operating, a heavy lifter can launch this and other satellites into orbit.

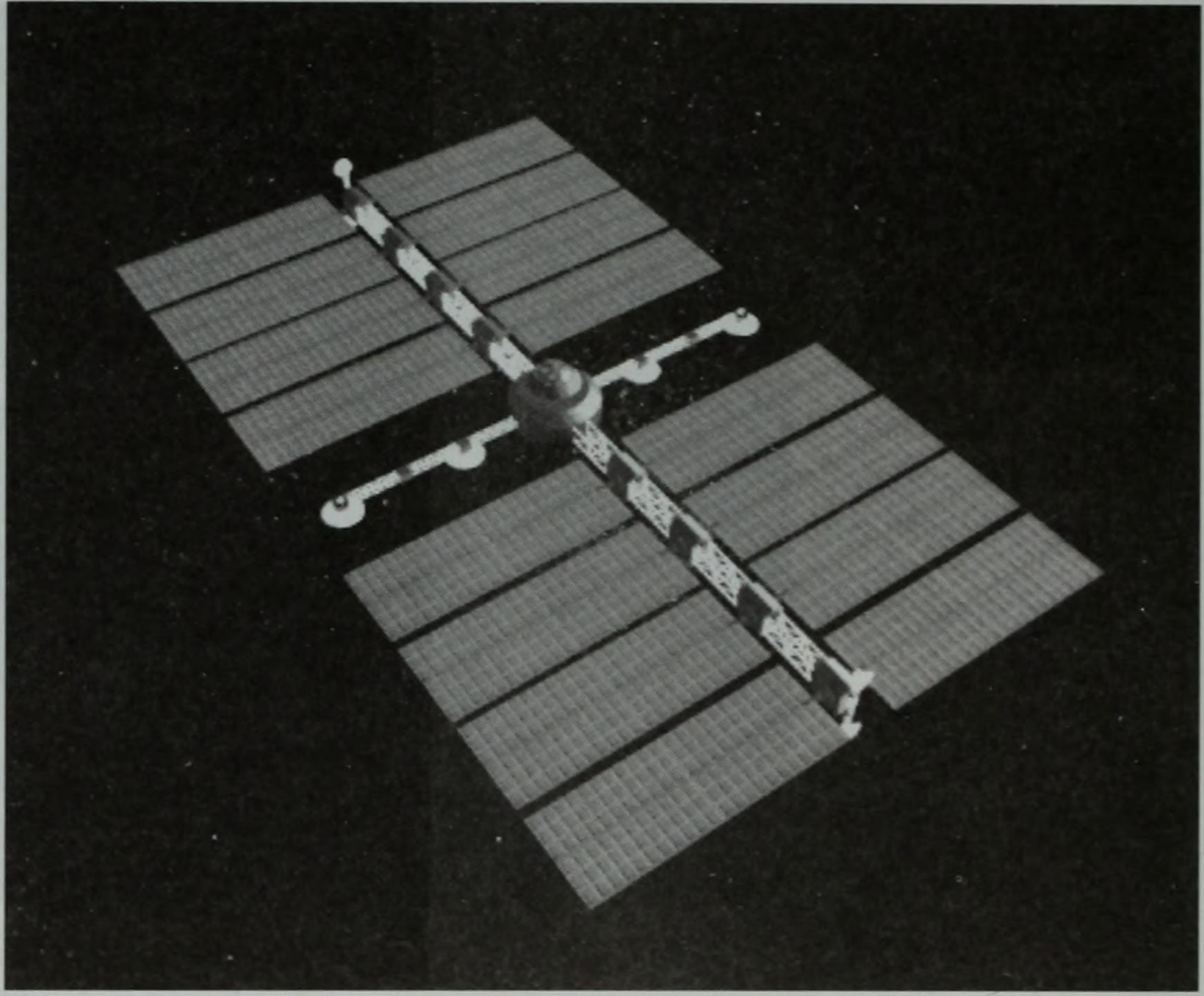


Figure 14-7

Solar power satellite

PHYSICS—Aerospace—Satellites and Probes—
Solar Power Satellite
50 turns required
Research into the solar powersat leads to the development of this orbital energy source. Once the space program is operating, a heavy lifter can launch this and other satellites into orbit. Figure 14-7 shows a powersat in orbit.

PHYSICS—Aerospace—Satellites and Probes—
Geological Penetrator Probe
50 turns required
Research in this area leads to the development of new geological penetrator probes. Once the space program is operating, a heavy lifter can launch this and other satellites into orbit.

PHYSICS—Aerospace—Satellites and Probes—Weathersat
50 turns required
Research in this area leads to the development of weather satellites for weather prediction. Once the space program is operating, a heavy lifter can launch this and other satellites into orbit.

PHYSICS—Aerospace—Satellites and Probes—
Orbital Observer
50 turns required
Research in this area leads to the development of the "orbital observer" satellite. We don't call this a spy satellite because that term has a negative connotation, as if we might by spying on the rebel colony or something like that, which we would never do, no, no, no. Once the space program is operating, a heavy lifter can launch this and other satellites into orbit.

PHYSICS—Aerospace—Satellites and Probes—
Interstellar Flyby Probe
50 turns required
Research into this area prepares for future colonization efforts through the development of the interstellar flyby probe. Once the space program is operating, a heavy lifter can launch this and other satellites into orbit.

PHYSICS—Aerospace—Satellites and Probes—ULBI Probe
50 turns required
Research into this area leads to the development of ultra long baseline interferometer probes to help you prepare for future colonization efforts. Once the space program is operating, a heavy lifter can launch this and other satellites into orbit.

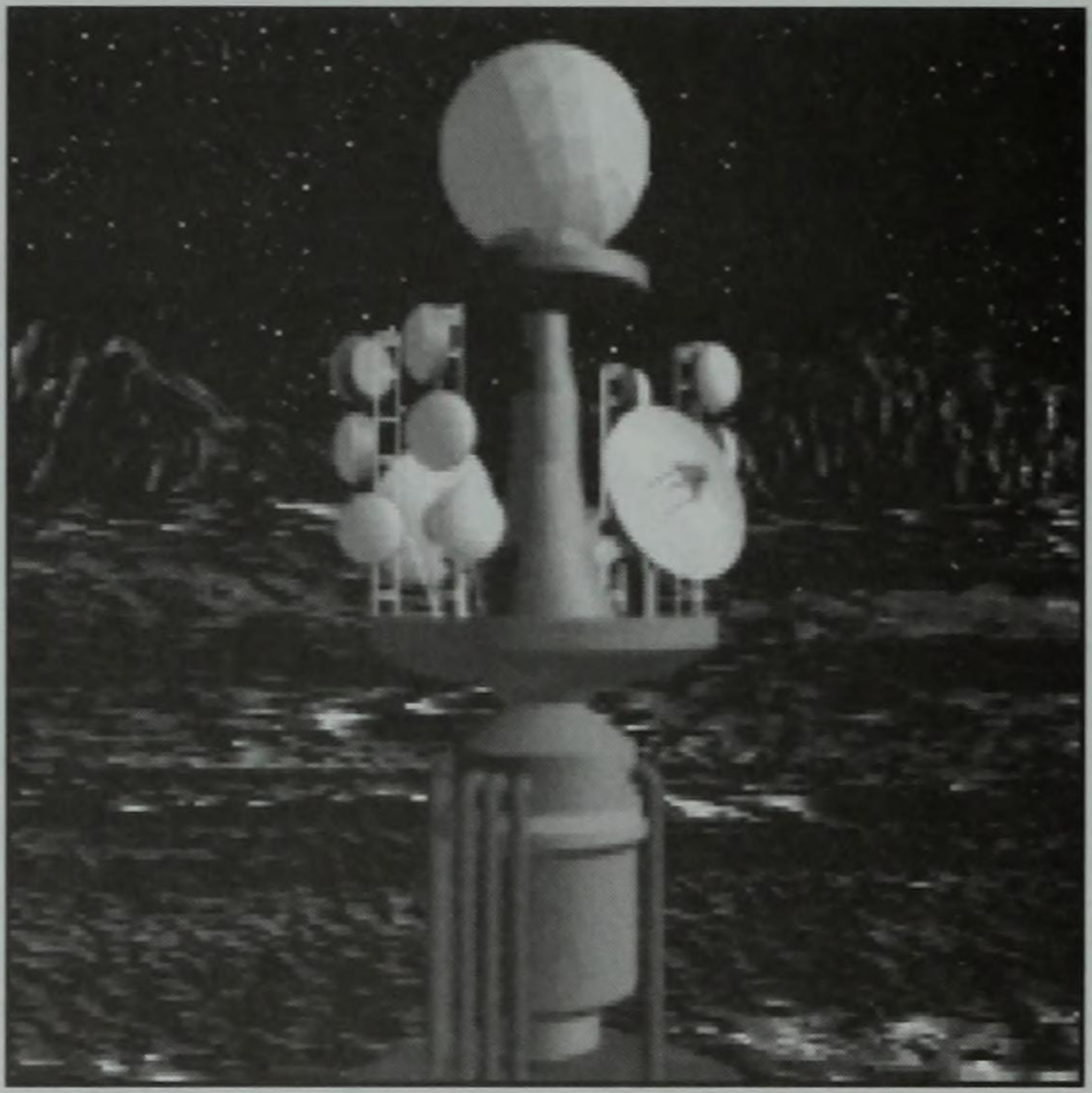
PHYSICS—Communications
25 turns required
Research into communications leads to proposed research on harsh environment signals processing for improved robot communications and on the search for extraterrestrial intelligence (SETI) radio astronomy project.

PHYSICS—Communications—
Harsh Environment Signals Processing
50 turns required
Research into harsh environment signals processing leads to improved communications on your new planet. Figure 14-8 shows an improved communications tower.

PHYSICS—Communications—SETI
100 turns required
Research into the search for extraterrestrial intelligence radio astronomy project will seek signals originating from other civilizations. You never know what you might find, if anything.

Figure 14-8

Advanced communications tower



PHYSICS—Orbital Mechanics
100 turns required
Research into orbital mechanics as it relates to the gravitational effects of your local planets is necessary to establish your new space program.

PHYSICS—Electrical Engineering
25 turns required
Research into electrical engineering is the basis for further research into robotics 2.

PHYSICS—Electrical Engineering—Robotics 2
100 turns required
Research into robotics 2 makes more complicated robots available to you if the other research into Computer Science— AI—Robotics 1 has been completed.

PHYSICS—Optics
100 turns required
Research in this area is required as a component of the meteorsat technology.

PHYSICS—Power Generation
25 turns required
Research in this area is required as a basis for further research into advanced alternative power systems.

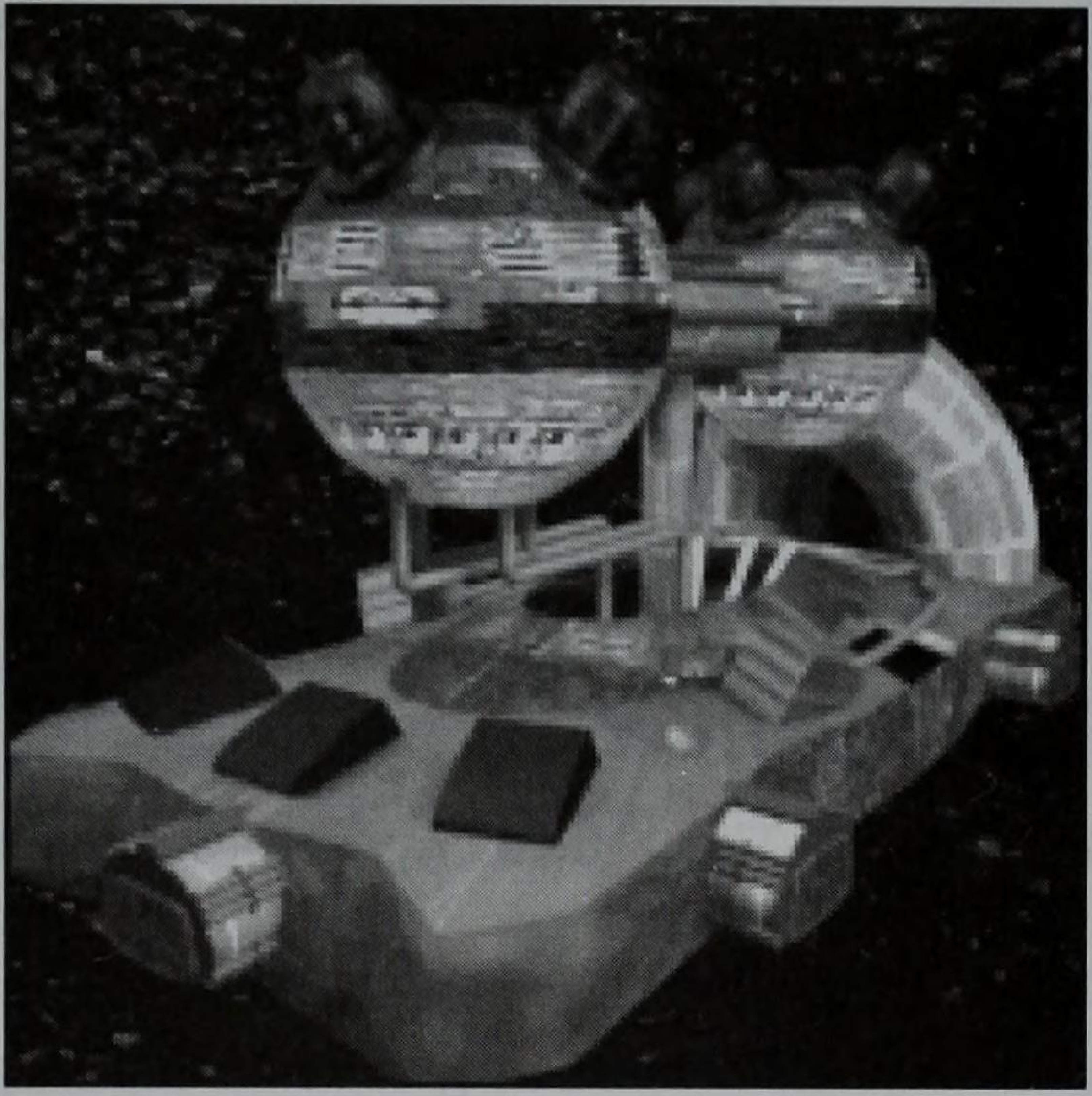


Figure 14-9

Geothermal power plant

PHYSICS—Power Generation—Advanced Alternative Systems
50 turns required
Research in this area results in the geothermal power facility shown in Figure 14-9.

PHYSICS—Propulsion Systems
25 turns required
Basic research in this area is required for further study on the subject of standard propulsion spacecraft.

PHYSICS—Propulsion Systems—Standard Propulsion
25 turns required
Research in this area leads to proposals for study of an asteroid miner, a heavy lifter, and a low-orbit freighter.

PHYSICS—Propulsion Systems—Standard Propulsion—Asteroid Miner
100 turns required
Research in this area generates the asteroid mining spacecraft, which can be placed in orbit once the new space program is active.

PHYSICS—Propulsion Systems—Standard Propulsion—Heavy Lifter
50 turns required
Research in this area generates the heavy lifter, a launch vehicle in the Saturn V category, which can be placed in orbit once the new space program is active.

PHYSICS—Propulsion Systems—Standard Propulsion—
Low-Orbit Freighter
50 turns required
Research in this area generates the low-orbit freighter, which can be placed in orbit once the new space program is active.

PHYSICS—Theoretical Physics
25 turns required
Research in this area is the basis for further research into antimatter, nuclear physics, plasma physics, superconductivity, and quantum mechanics.

PHYSICS—Theoretical Physics—Antimatter
100 turns required
Research on the subject of antimatter contributes to the general pool of physics knowledge and could be applied to future exotic propulsion systems.

PHYSICS—Theoretical Physics—Nuclear Physics
100 turns required
Research on the subject of nuclear physics is useful for further development of fusion technology and the maintenance of any tokamak fusion reactors you might have.

Figure 14-10

Mass driver launch

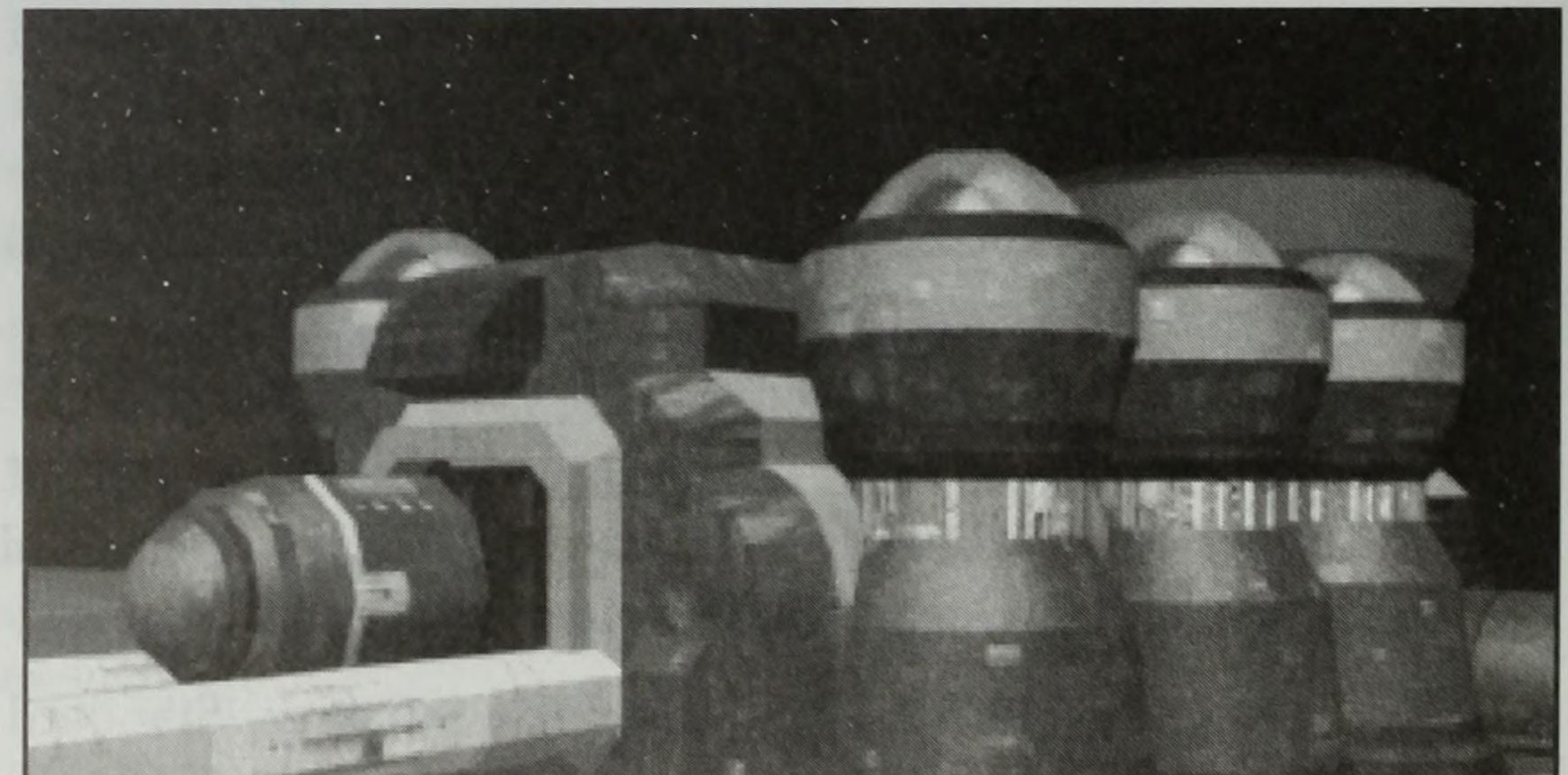


Figure 14-11

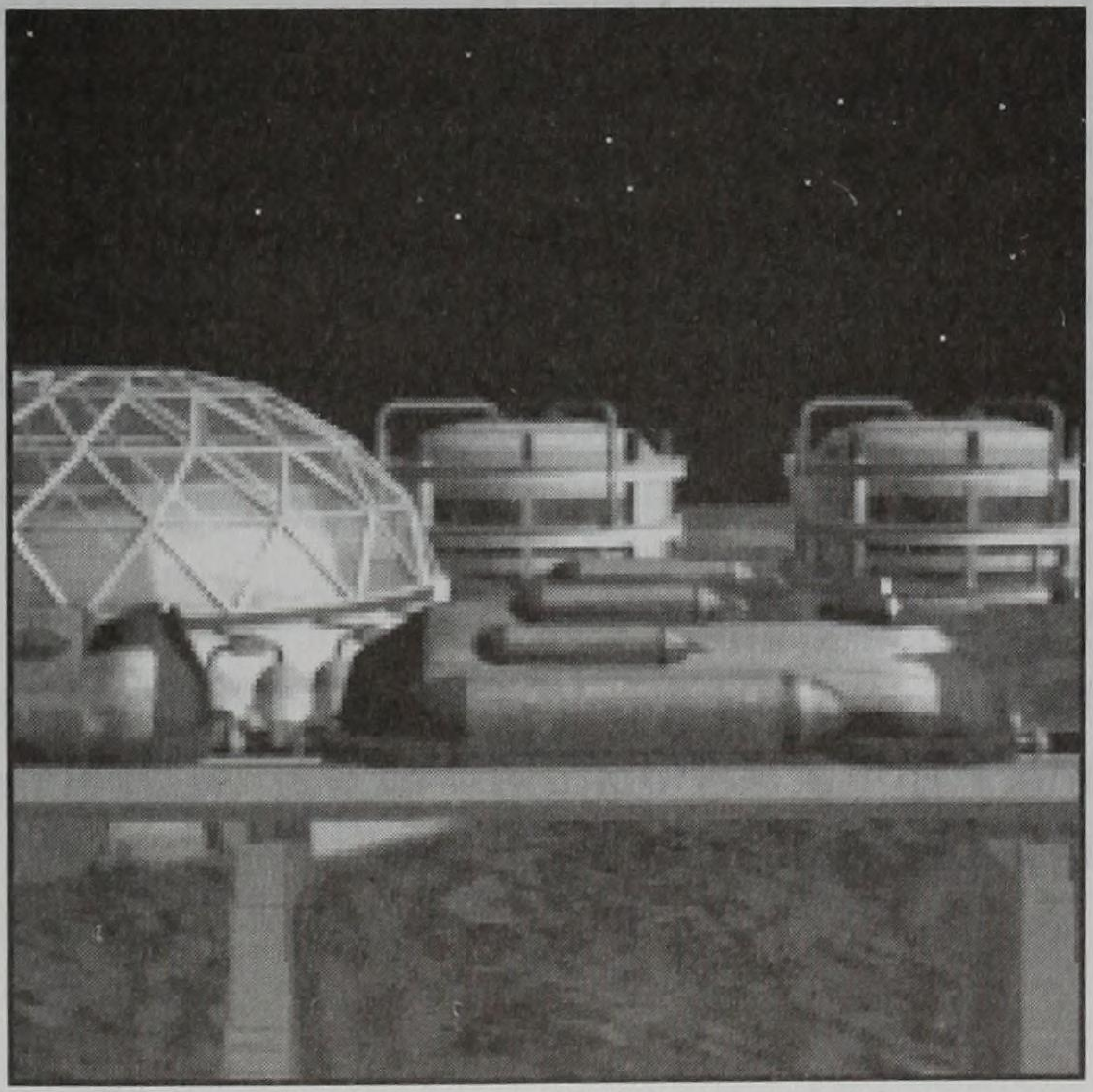
Monorail in operation

PHYSICS—Theoretical Physics—Plasma Physics
100 turns required
Research on the subject of plasma physics is useful for further development of fusion technology and advanced forms of tokamak fusion reactors.

PHYSICS—Theoretical Physics—Superconductivity
100 turns required
Research into superconductivity is a major component leading to the development of the mass driver, shown in Figure 14-10, and the monorail, shown in Figures 14-11 and 14-12.

Figure 14-12

Monorail passing through town



PHYSICS—Quantum Mechanics
100 turns required
Basic research in quantum mechanics is a necessary component leading to nanotechnology development.

PHYSICS—Quantum Mechanics—Nanotechnology 2
100 turns required
Research into nanotechnology 2 is a necessary step in the development of nanomachines.

PHYSICS—Quantum Mechanics—Nanotechnology 2—Nano-machines
200 turns required
Research into nanomachines is a necessary step in the development of assemblers and replicators.

PHYSICS—Quantum Mechanics—Nanotechnology 2—Nano-machines—Assembler
50 turns required
Research in this area, combined with nanotechnology 1, leads to construction breakthroughs.

PHYSICS—Quantum Mechanics—Nanotechnology 2—Nano-machines—Replicator
50 turns required
Research in this area, combined with nanotechnology 1, leads to construction breakthroughs.

PHYSICS—Quantum Mechanics—Nanotechnology 2—Nano-machines—Construction
50 turns required
Research in this area leads to construction breakthroughs. The construction of robots, satellites, probes, spacecraft, and colony structures will be much easier when this research is completed.

PHYSICS—Quantum Mechanics—Nanotechnology 2—Nano-machines—Medical
75 turns required
Research in this area leads to medical breakthroughs. Vast improvement in the population's health will become evident when this research is completed.

PHYSICS—Quantum Mechanics—Nanotechnology 2—Nano-machines—Mining
25 turns required
Research in this area leads to mining breakthroughs.

PHYSICS—Quantum Mechanics—Nanotechnology 2—Nano-machines—Terraforming
25 turns required
Research in this area leads to terraforming breakthroughs, in combination with other research.

PHYSICS—Quantum Mechanics—Nanotechnology 2—Nano-machines—Food Production
25 turns required
Research in this area leads to food production breakthroughs.

SOCIAL SCIENCES—Economics
50 turns required
Research in this area results in an improved exchange rate for trade negotiations

SOCIAL SCIENCES—Political Science
50 turns required
Research in this area results in an improved trade posture for trade negotiations.

SOCIAL SCIENCES—Psychology
50 turns required
Research in this area improves the morale of your population. This also leads to further research in the areas of trade negotiation and advanced teaching methods.

SOCIAL SCIENCES—Psychology—Trade Negotiation
50 turns required
Research in this area results in an improved trade posture for trade negotiations.

SOCIAL SCIENCES—Psychology—Advanced Teaching Methods
100 turns required
Research in advanced teaching methods results in an enhancement of the educational effect of universities you may have built.

SOCIAL SCIENCES—Sociology
25 turns required
Basic research in sociology leads to further study in crowd psychology, industrial sociology, social stratification, and cultural change.

SOCIAL SCIENCES—Sociology—Crowd Psychology
100 turns required
Research in this area negates the effect of Police units with a fascist attitude.

SOCIAL SCIENCES—Sociology—Industrial Sociology
100 turns required
Research into the sociology of the factory environment leads to improved factory production because of happier employees.

SOCIAL SCIENCES—Sociology—Social Stratification
50 turns required
Research into the class structure of your society helps you convince the population that everyone is equal on this new world. Morale improves.

SOCIAL SCIENCES—Sociology—Cultural Change
50 turns required
Research on the topic of cultural change helps you convince the population that the mix of cultures among the colonists is the best combination the Earth had to offer and it will help them preserve Earth traditions. Morale improves.

SOCIAL SCIENCES—Urban Studies
25 turns required
Research into the dynamics of the colony and how it operates is a basis for further research into city planning.

SOCIAL SCIENCES—Urban Studies—City Planning
100 turns required
Research into city planning shows you when you might be making serious mistakes in the construction of your colony facilities. Excessive behavior will now be noticed by your AI, who will warn you when you've obviously gone off the deep end.

SOCIAL SCIENCES—Police Science
50 turns required
Research into police science shows you how to control the police properly. The area affected by Police units will show greater control when you have completed this research.

HUMANITIES—Drama
50 turns required
Research in this area improves the morale of your population.

HUMANITIES—Fine Arts
50 turns required
Research in this area improves the morale of your population.

HUMANITIES—History
50 turns required
Research in this area improves the morale of your population.

HUMANITIES—Music
50 turns required
Research in this area improves the morale of your population.

HUMANITIES—Philosophy
50 turns required
Research in this area improves the morale of your population.

End Results

Although they were mentioned in the research descriptions, certain end results and discoveries from the research efforts bear mentioning a second time. The end of a particular branch of the research tree can lead to new technologies and structures, hardware such as robots, new lines of research, or improvements among the population of your colony.

New technologies and structures generated from research:

Geothermal power plant
Nanotechnology facility
Terraforming facility
Mass driver
Monorail

The following is a handy summary of the research needed for specific goals generated through the research program.

Research needed for space program:

Astrophysics
Extraterrestrial mining
Celestial mechanics
Standard propulsion spacecraft
Mathematics
Wind tunnels
Spacecraft testing and analysis

Research needed for terraforming:

Terraforming microbe
Exobiology
Alien ecology

Research that improves morale among the colonists:

Humanoid workers
Psychology
Cultural change
Social stratification
Drama
Fine arts
History
Music
Philosophy

Research that improves the health of the population:

Anatomy
Comparative physiology
Embryology
Immunology
Nanotechnology—medical

Research that improves colony communications:

Harsh environment signals processing

Research necessary for multiple artificially intelligent managers you can trust:

AI managers
Advanced processors
AI personality problems

Research necessary for improved trade results:

Economics
Political science
Trade negotiation

Laboratory research is an important ingredient in advancing the state of your civilization and demonstrating to your colonists that you know what's best for their continued survival and happiness. As far as the population is concerned, the products of your scientific research programs demonstrate that the accumulated knowledge of civilization will not die with them and that there's hope for the future, no matter how bad things may seem.

This chapter has delivered the secrets of *Outpost* science into your hands, enabling you to take shortcuts toward reaching specific research goals. Knowing how long it takes to reach those research goals is also a great relief in strategic resource planning for your colony.

The next chapter probes into the topic of artificial intelligence. AI managers have been mentioned several times, but perhaps you've been pondering that philosophical question of the workplace: "Aren't all managers artificially intelligent?" Because I'm a manager myself, and I have a degree in artificial intelligence, I can answer that question with an unqualified "yes." However, there are other aspects to artificial intelligence within this game. For example, how do you prevent AI personality problems? How do you know when your AI is sick or unbalanced? Is an AI really a person stuck inside a computer? Can you trust your AI? Does the AI dream? Is the AI smarter than you? Many of these questions, and more, are answered within the next few pages. I can't wait! Turn the page!

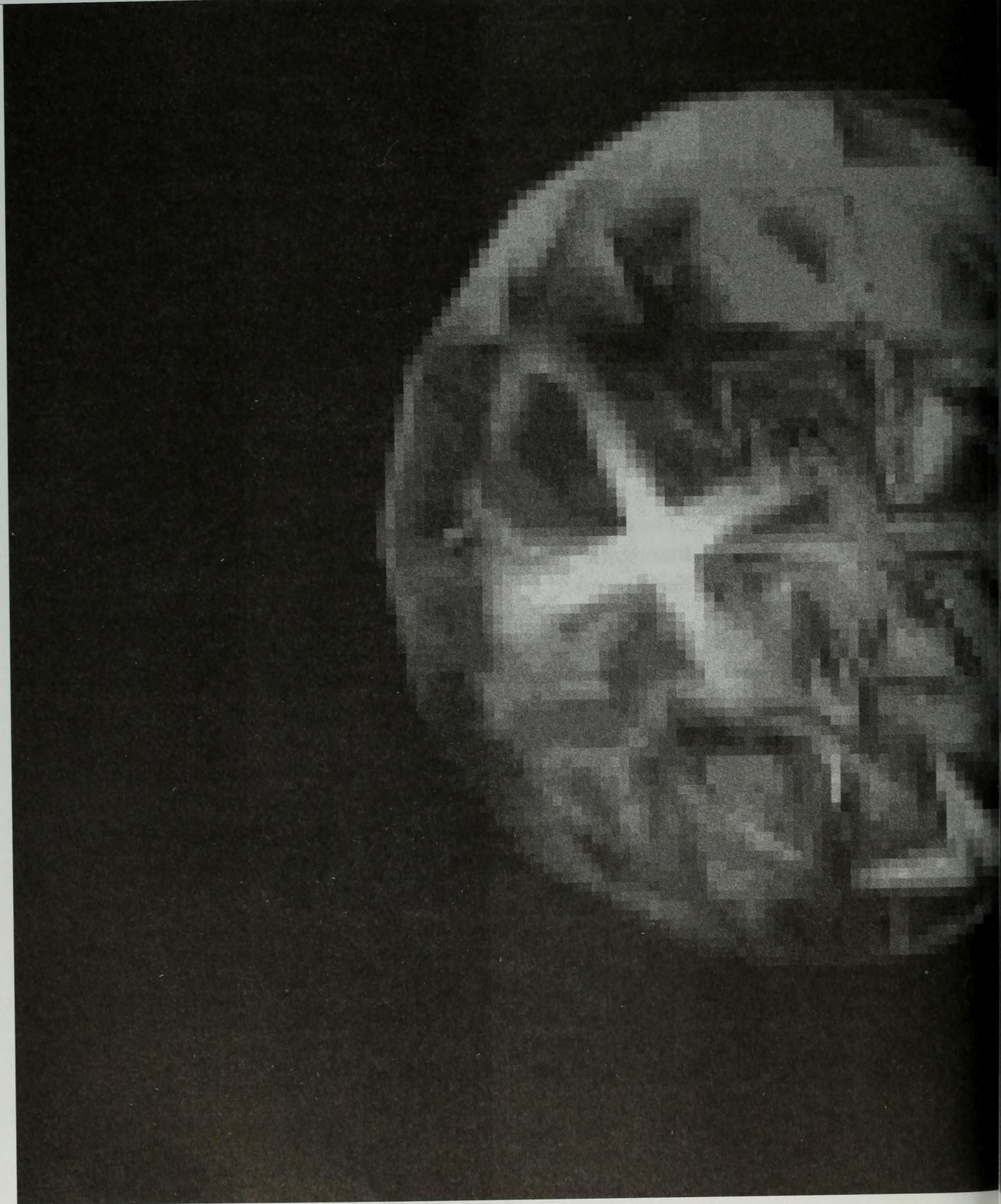
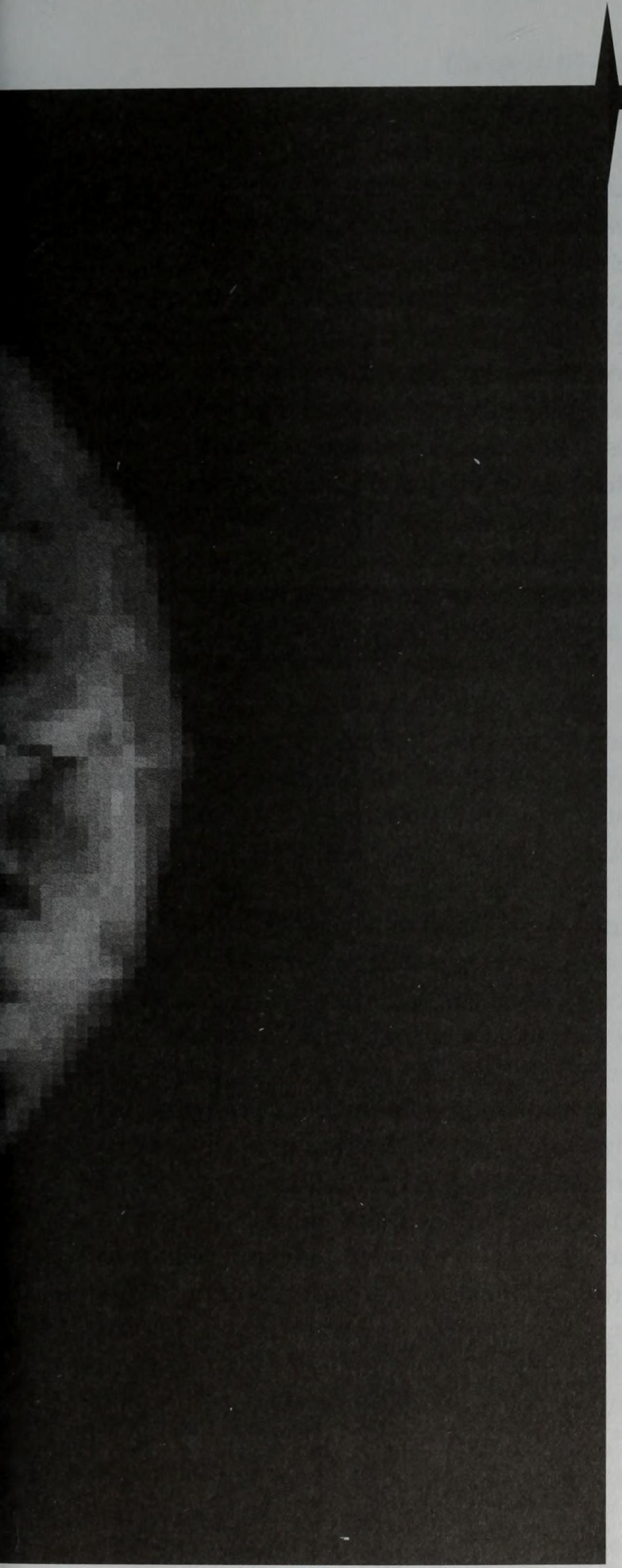


Figure 15-1 Your artificially intelligent adviser



15

An Artificial Intelligence with Personality

The real danger is not that computers will
begin to think like men, but that men will
begin to think like computers.

Sydney J. Harris

As our tools become more intelligent, complex tasks become simpler for us to complete. The pilot of a modern jet fighter is almost a cyborg, half man and half machine, as he flies through the air connected to the sophisticated sensory and command equipment of his aircraft. His eyes may be enhanced by night vision equipment, his flight path low over the ground may be controlled by terrain following radar with reactions faster than his own. In the newest systems, eye movements reflecting the pilot's thoughts are sensed by lasers for translation into targeting and flight commands. The aircraft itself makes many of the flight decisions with a primitive form of artificial intelligence (AI). Robots flew over Iraq during the Persian Gulf war. Although many years will pass before a sophisticated artificial intelligence appears, it's apparent that the technology is well on its way. This chapter gives you a brief introduction to the artificially intelligent adviser who lives within *Outpost*.

The AI as Manager and Scientist

Your master AI adviser is the first of many who will become available to you during the game, but it is also the most dynamic and multifaceted. Most of your actions during the game will be directed through the AI, and its Chrome Ball icon, as shown in Figure 15-1, will remain at the lower left corner of the main interface screen, patiently awaiting your orders while you build your colony.

If you wish to initiate diplomatic relations or a trade session with another colony, it will be directed through the AI. If you need help or you want to take a look at the master status reports, the AI will assist you. The AI will warn you of impending doom, alert you to important events, and summarize news reports for your attention.

In addition, the AI can be assigned to research or administrative tasks, which it will perform with speed and efficiency to the best of its ability. Although it may require some guidance from you when performing these tasks, it will lighten your administrative load, leaving you free to handle more important decisions. When the time comes for you to leave your new planet, if you choose to do so, the launch command will go through the AI. The AI is your digital friend. Depend on your AI for all your administrative needs.

Alerts and Disasters

Some planetary events require specific types of equipment to give you any warning that they're about to happen. For example, a weather satellite (weathersat) is necessary for warnings of powerful dust storms approaching your colony. Satellites that provide other warnings are described in Chapter 13. If a situation is occurring that requires your immediate attention, and the proper equipment is in place to sense the problem, your AI adviser will give you an alert. This alert, given by the excited AI as it appears in Figure 15-2, will tell you about the problem and request your immediate action. In the case of a solar flare, the AI would warn you about it, then ask if you want to evacuate your colonists from the surface for protection underground. If you want the colonists to ignore the solar flare and continue working, that's your choice, but you won't receive a kind mention in the newspaper that day.

News Briefs

One of the services performed for you by your master AI is the headline scanning service. The *Outpost Evening Star* is the colony newspaper, reporting on major events in the colony, including many of your decisions. Strategies for manipulating the media to your benefit are given in Chapter 20. Instead of slowing you down with too much information, the AI scans the news for events related to you and posts them as news briefs. These news items can range from the first birth among the colonists to impending events such as solar flares. When the editor of the newspaper seeks an interview, that request will also come through your AI adviser.

Where Can I Get More of These Handy AI Helpers?

Your master AI is a powerful creation that depends on powerful computer support to do its job. Such computers are in short supply when you land on your new planet, so you'll be limited to one AI adviser until such time as you can perform computer science research. Study in artificial intelligence and advanced processors will eventually lead to a new line of research ending in AI managers. These AI personalities are not as impressive as the master AI, but they are able to communicate and administer simpler tasks that can make your job easier.

Figure 15-2

AI in alert mode

For example, macromanagement allows you to assign an AI personality to the administration of an entire colony. If you have multiple colonies, you'll probably find that the number of decisions required per colony per turn becomes too great to handle in comfort, so any help you can get will be welcome. These AIs can be assigned lists of tasks you wish them to complete over a long period. To make sure that they're reliable, new AIs should be watched closely the first few times you use them.

AI Personality Problems

When your computer scientists develop the first AI personalities on your planet, they'll be at an early stage of development, almost like children that need to be trained. Although the new AIs will be able to perform administrative and research tasks to help you, they may show signs of being imperfect at times. If you issue an order to one of your colony administrator AIs that you want a new agricultural dome to be built every 10 turns, and you end up with four new communication towers instead, this should alert you to the fact that your new AI has a personality problem.

Research into AI personality problems will take care of this unfortunate situation for you. Until that time, you need to be careful as to what orders you issue to your problem children. Also be wary of any advice they may offer before their personalities have stabilized.

This chapter has given you a brief introduction to your AI adviser and the potential problems of multiple AI personalities. The next chapter will turn you into a successful diplomat, spy, opportunistic developer, and trade negotiator.

Figure 16-1 Trade Mission

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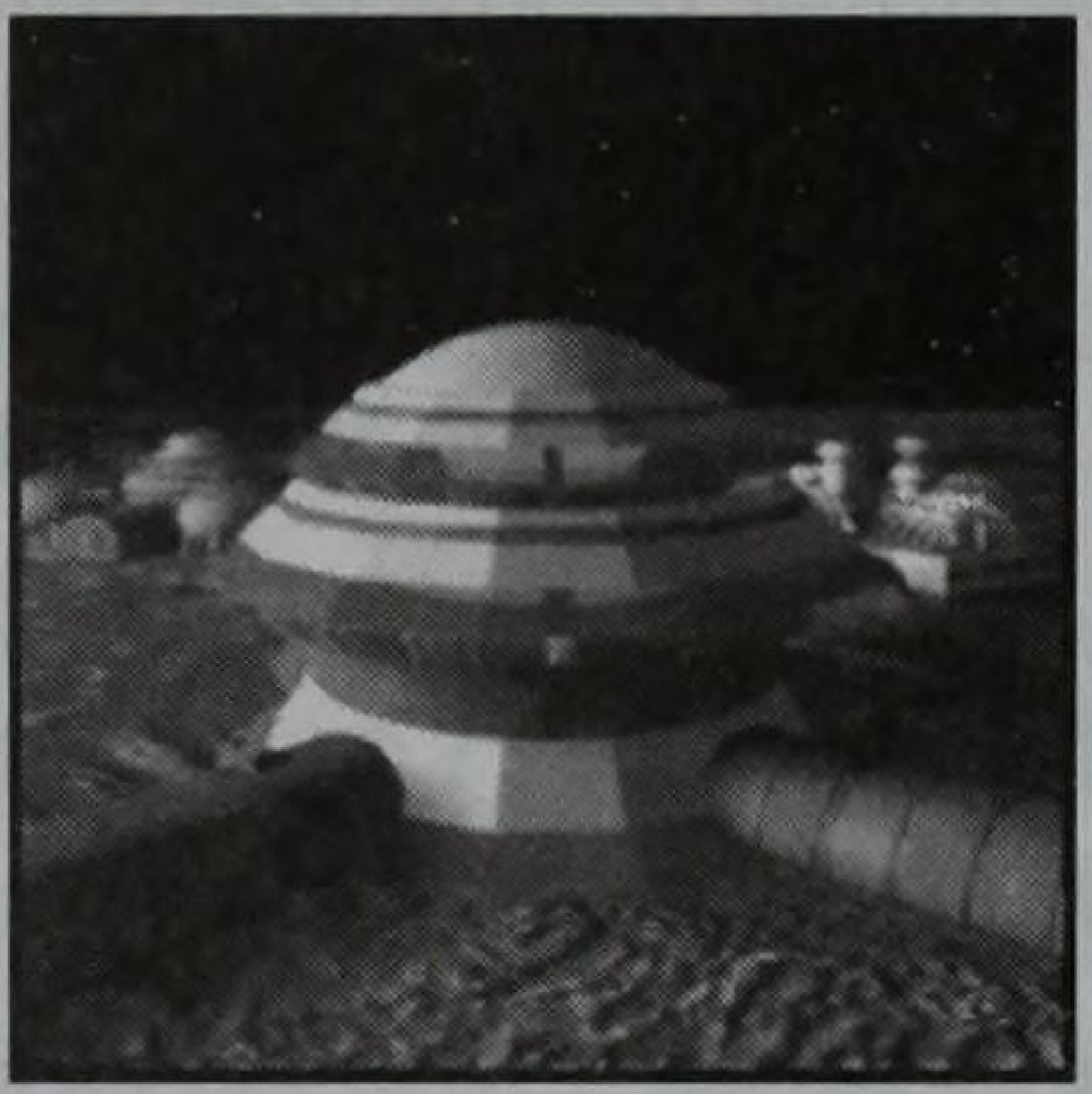


Trade: How to Win Friends and Influence People

A real diplomat is one who can cut his neighbor's throat without having his neighbor notice it.

Trygve Lie

When you arrived at your new planet, a rebel group took off with half of your equipment and supplies. They formed a colony of their own, thumbing their noses at your ability to run a civilization. As your colony prospered, theirs did also. As your colony floundered, the rebel colony still flourished. This seems inherently unfair, but there's something you can do about it. Take advantage of the situation. Establish trade with the rebels and sneak off with their wealth in broad daylight. After all, that's what diplomacy is all about, right?

In this chapter, you'll learn how to take advantage of your neighbors through trade.

Diplomacy: Professional Acting

When you initiate diplomatic relations with another colony, whether it's a rebel colony or one of your own, and your advances are accepted, your trade partner will offer to build a Trade Mission in their colony for you. This building costs you nothing. All you have to do is have one person available to staff that building, which is essentially your embassy. Your trade partner also provides the resources to maintain the new structure. Once it has been built, you can engage in unlimited "free" trade with that colony.

Intercolony Commerce

Trade between your own colonies, or between you and the rebel colonies, will provide a certain amount of security in terms of available resources. If your mines are about to dry up, you can always arrange an exchange with another colony if they have the surplus resources you require. Of course, the establishment of a trade agreement also means that you're going to build a Trade Mission for your trading partner in your colony, free of charge, that you will also have to maintain. Such is the price of free trade.

The Barter System: An Eye for an Eye

Trade between colonies is composed of a barter system. You offer something to trade, and they tell you what they're willing to offer in return. You can accept or reject their offer, then make another attempt, and so on until you both reach an agreement on what to exchange.

You have the option of trading your surplus resources, buildings, mines, research, people, robots, or even whole colonies if you're desperate. Surplus resources are the primary commodities during trade sessions, but you may end up trading one of your factories in return for one of their mines, or five of your people for one of their Agricultural Domes.

Exchange Rates: An Eye for an Agricultural Dome

The initial exchange rate between colonies is based on the difficulty level you select at the beginning of the game. This exchange rate will vary, depending on your last transaction with a particular colony, and whether you have taken advantage of the trade agreement to sneak new structures into their colony. If you annoy them, the exchange rate will favor them.

Economic Warfare

There is no formal combat in *Outpost* because it would not have fit in with the realistic tone of the game. However, you do have an economic competitor in the rebel colony. If it turns out that the rebel colony is located near your own, you may find that you're both competing for the same local resources. If the rebels get there first, their mines may produce more of the unusual elements than you're able to find, placing you in the position of asking to buy some of those elements to maintain the functioning of your colony. This is embarrassing for everybody, so try not to let it happen.

Because you may also end up in the situation of mining resources that the rebels desperately need, a balance can be achieved between the colonies if you establish regular trade sessions to exchange those resources. This is a pleasant situation, but it also puts you at the mercy of your trade partner.

If you find yourself in the situation in which you have surplus amounts of a resource that another colony requires, you can dominate the trading session and receive far more in the way of benefits than the resources you're trading are actually worth. If this occurs for two consecutive trading sessions, your third trading session will have the added bonus of a surplus balance of trade, even if you don't have surplus resources for bargaining. The opposite of this is a balance of trade deficit, which occurs when imports were greater than your exports during the previous one or more turns. Avoid a deficit and you will dominate the negotiation.

Trade Strategy

When you're involved in a trade session, the party that has the most surplus resources has a trade advantage. If you think ahead a turn or two, you can get this advantage by manipulating your supply of resources before a trade negotiation. While maintaining your mine production, shut down some of your facilities so that they aren't drawing any resources for a few turns. After the trade session, you can restart the idle facilities and return operations to normal.

If you really want to annoy the other colony, you can start sneaking new buildings into their colony. They hate this sort of thing, not only because they've been gracious enough to sign a trade agreement with you, but because those new buildings use their energy and their resources, even though you own them and staff them. They may not notice your new buildings immediately, but they will probably break off the trade agreement with you as punishment when they discover what you're doing. They will also claim one of your new buildings as their own. But all is not lost.

After a trade agreement has been broken because of your new buildings, you can wait a few turns and offer a new trade agreement. This may or may not be accepted. If it is accepted, the exchange rate will be worse for you because they aren't going to trust you for a while. Once they trust you again, you can sneak a few more new buildings into their colony to suck up some more of their resources. When they catch on to what you're doing, they will no longer sign any trade agreements with you and they'll shut down your Trade Mission in their colony. If the Trade Mission is shut down, you won't be able to build any new structures there. If they're really worried about you, they'll surround your new buildings with their Police Stations to prevent further expansion.

This strategy may also be used on you by the rebel colony. If you establish trade with them, a Trade Mission will be built in your colony at your expense. They can use this base for building new structures. If you don't break off the trade agreement, they will continue to sneak new buildings into your colony. The only other way to prevent further expansion is to build a complete ring of your own structures, such as Police Stations, around each of their buildings. Every building they create will be a draw on your resources and power. If you break the trade agreement, you can bulldoze their buildings or gradually make them your own by annexing them to your colony.

Covert Intelligence Gathering

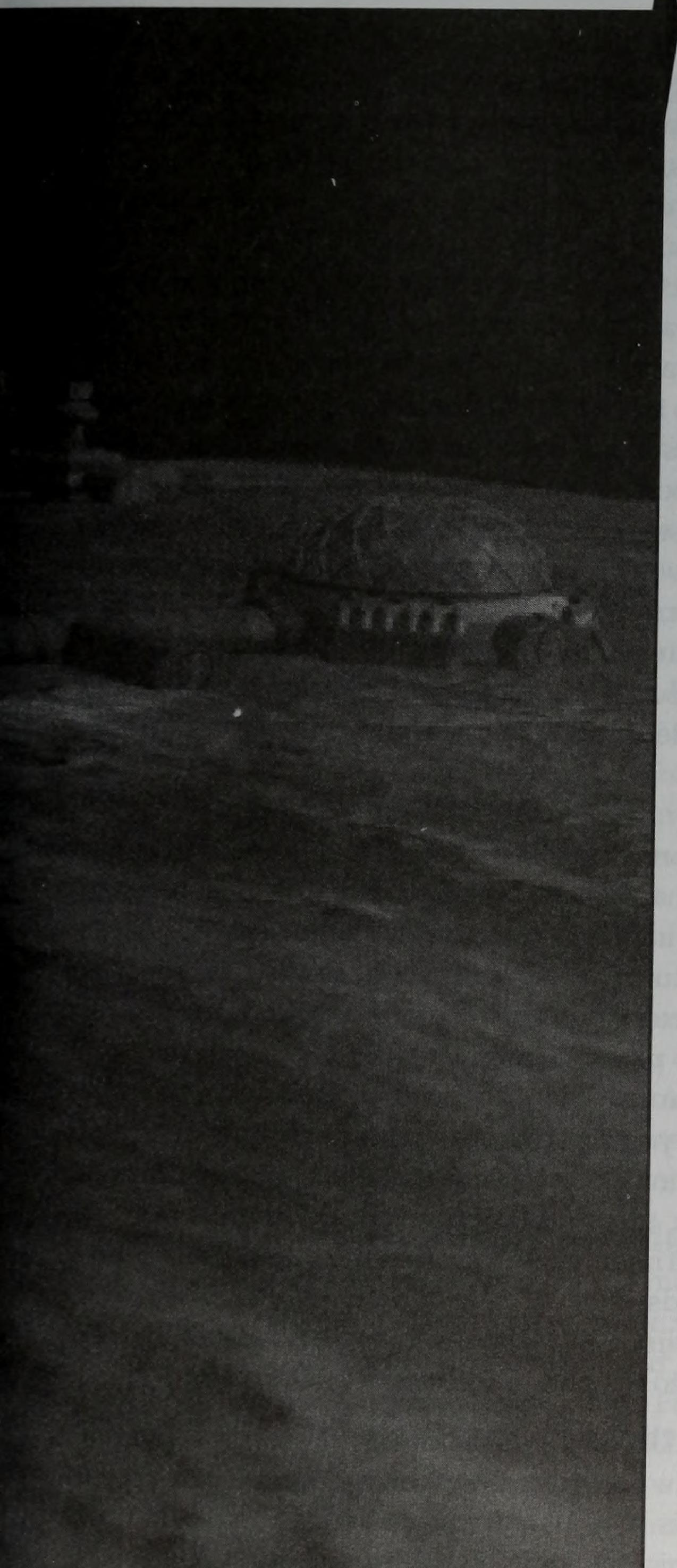
The orbital observer is a handy satellite to have if you want to keep an eye on what your neighbors are doing. With this satellite, you can get an overhead view of the rebel colony, allowing you to keep track of how well the colony is developing and what kind of structures they're building. This knowledge gives you an advantage in establishing trade, because it's a lot like sneaking a peek at someone else's cards while you're playing poker.

If you have a Trade Mission already built in someone's colony, your staff member will perform intelligence gathering. This means that a spy satellite is unnecessary while an active Trade Mission exists, because both methods allow you to see the buildings in that colony.

In this chapter, you've learned some of the sneaky tricks of diplomacy and trade. You've also learned how to annoy your neighbors and receive material benefits from doing so. The methods for keeping an eye on the rebel colony were also explained.

In the next chapter, I'll discuss the meaning of victory in *Outpost* and how you can pursue different goals in the game. I'll also explain a clever strategy for emptying out the rebel colony that you can combine with the trade strategies I've just discussed to engineer a massive takeover of rebel assets. What could be more satisfying than getting economic revenge on the same people that stole half your supplies when the game started?

Figure 17-1 An expanding colony



17

Victory Conditions

If at first you don't succeed, try, try, again.
Then quit. There's no use being a damn fool
about it.

W. C. Fields

Yes, you can have, create, do, and achieve anything you want out of life! It's true! In only minutes, you can become the master of your universe, a force of nature, the leader of human civilization! With a few spare hours, you can conquer the hostile environment of a new planet! With your bare hands, you can control thousands of tiny electronic lives and force them to do your bidding! You can build a civilization such as the world has never seen, and never will again! You can create robot servants and make them work 24 hours a day out of loyalty to you! With the power of your mind, you can force a planet to its knees, then create an atmosphere so that the environment itself will stand as a monument to your greatness! When people look up the definition for "success" in the dictionary, they can see a photograph of you! Sure, everyone laughed at you when you were young, and they said you'd never amount to anything, but look at how they worship you now! The power of life and death is at your command!

Now that I've just described what *Outpost* is really all about, let's look at the technical definitions of victory within the confines of this game.

What Does It Mean to Win?

As with any simulation, it would be easier to define *Outpost* as a complex toy, rather than a game. The only real rule is survival, with progress thrown in for good measure. That progress is necessary to continue the survival of civilization, so it's really just an extension of the one rule. But, this is a nontraditional game category, and we want to please as many people as possible, so there are goals you can aim for if you're so inclined. These provide milestones against which you can measure your performance. If you prefer to set up situations, save the game state, then test different strategies to see how the simulation responds, there's nothing wrong with that experimental approach to the game. Your planet awaits your commands.

For those of you inclined to be goal-seeking organisms, the following are the paths to success in the world of *Outpost*.

World Conquest through Attrition

Let's say that you're a clever person (and we know you are because you bought this book), and you've noticed that when the morale of your colonists drops down low, and stays there, you start losing people. They just seem to disappear. It's quite annoying. Then, in a moment of insight after studying your navel for 14 hours, you realize that your colonists pull up stakes and hit the road whenever things get bad.

Well, it's true. Morale is very important. The cynics among your colonists are going to be watching your every move. If it looks like you've lost your mind, you're disorganized, you're a bad manager, you're incompetent, or you're just showing signs of feeble-mindedness, the cynics are going to leave town to look for greener pastures elsewhere. You may think you've got a captive audience, but there's a rebel colony out there, remember? Those filthy scum that took off with half your supplies when you arrived at the new planet? Well, they've been off developing their colony while you were developing yours. If your population starts migrating over to the other side, it just makes things better for the rebel colony. However, there's a flip side to this phenomenon.

If you can keep the morale high among your own colonists, you'll start to acquire a few extra people to staff your labs and factories. This is a good thing. If you're managing your resources properly, the extra people won't be a burden on your economy. Life will be good. The birds, if there were any, would sing your name in the trees, if there were any.

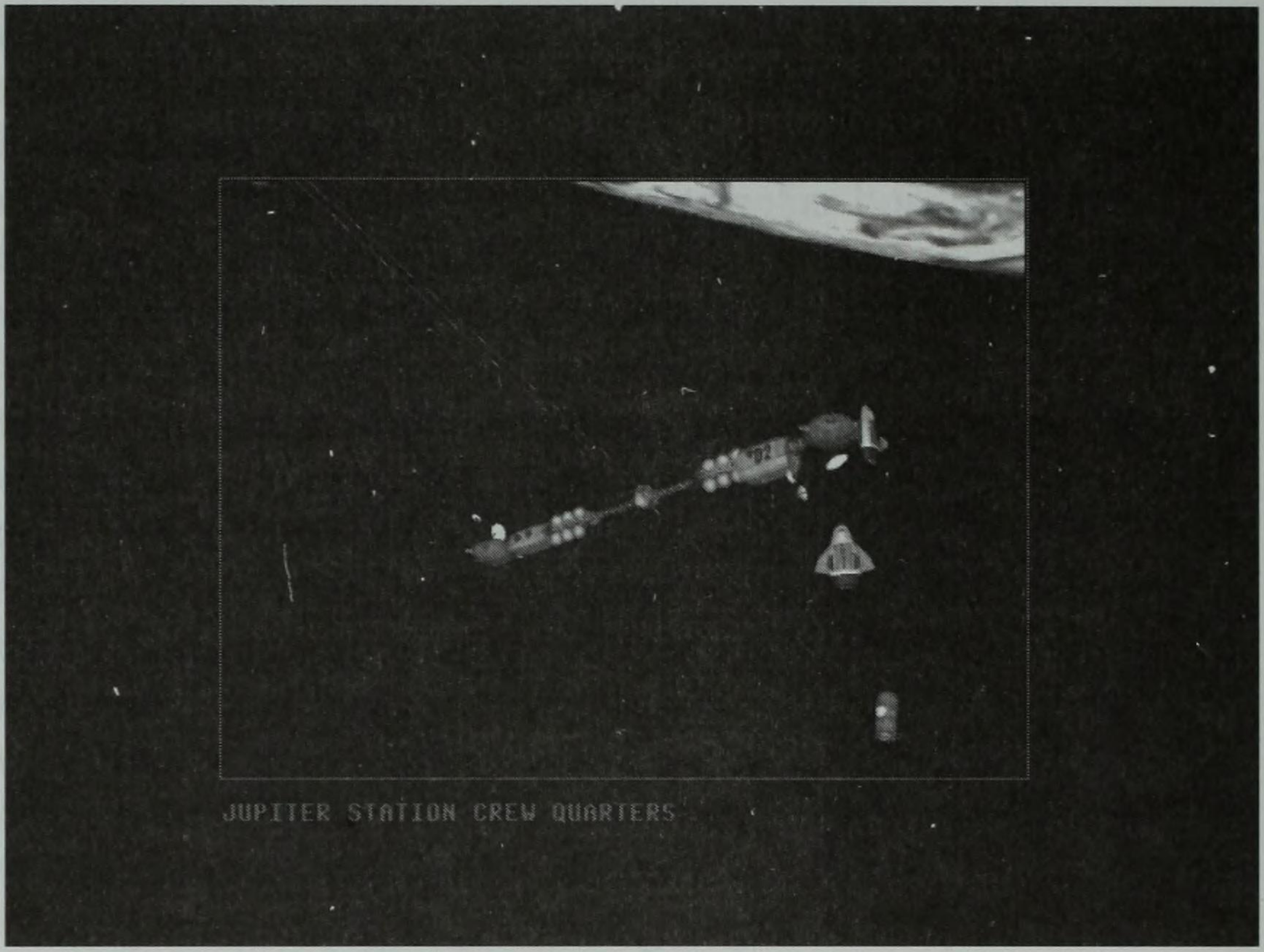
Let's say the entire rebel population decides you're one clever administrator who is wise and all-knowing, and they all defect to your colony. Then the rebel leader realizes he made a big mistake, so he acknowledges he was wrong and defects to your colony. Well, there's an entire, developed, but abandoned colony sitting out there waiting for you. As long as it's empty, you can make it yours, along with its resources, mines, buildings, robots, factories, research, and transportation systems. This can be a real gold mine if you're clever enough to accomplish it.

Command the High Ground

Maybe you need a more traditional sort of goal that makes you feel like you've come full circle in the game. In that case, develop your civilization and research to the point that you can rebuild your space program. Figure 17-2 shows a new space station in orbit. As progress is made along the way, you can connect remote landing sites on the planet with low-orbit freighters to create a global economy; you can mine any asteroids that might be hanging around in the local area; and you can launch satellites for power, meteor defense, and observation of the planet. As all your lines of research come together, and your technology has advanced to a

Figure 17-2

Orbital space station



high level, you can build a new starship and set off in search of new worlds to conquer. You can't actually reach those other worlds in this game, but you will have managed to complete the circle and prove that human civilization will survive among the stars.

Subgoals

There are a variety of technological and civilization goals you can attain in your quest for greatness. These accomplishments will usually be announced in the colony's electronic newspaper, *The Outpost Evening Star*. Remarkable trade agreements, the first birth on the colony, the first death on the colony, research discoveries, the establishment of new colonies, the building of the spaceport, the crash of the starship's hulk from orbital decay, major planetary discoveries, successful recovery from major natural events, and demonstrations in your honor due to long periods of high morale, will all be noted in the newspaper.

The completion of certain lines of research will have major effects on the operation of your colony. Nanotechnology will make your life simpler by increasing your ability to produce useful things from your factories, while lessening your dependence on resources. The commencement of terraforming will create major improvements in the morale of your population.

Do You Have What It Takes to Be a Winner?

Many of the goals in *Outpost* will be those you define yourself. Make plans, take charge, and take action. Demand more from yourself than anybody else could ever expect. Treat the simulation as if it's as realistic as it was meant to be, poke it and see what happens, learn from experimentation, and play to win. Strive for the goals you set, meet them, and set new goals that stretch your limits even more. Manage your people, conquer the environment, develop your science and technology, and win one for the gipper, whatever that means.

Now that you're motivated to take full command of the situation, and you know the meaning of victory, let's get into the details of how to manage your new planet, keep morale high, and handle emergencies as if you've been doing it all your life. These things, and more, patiently await your eyeballs in the next chapter.

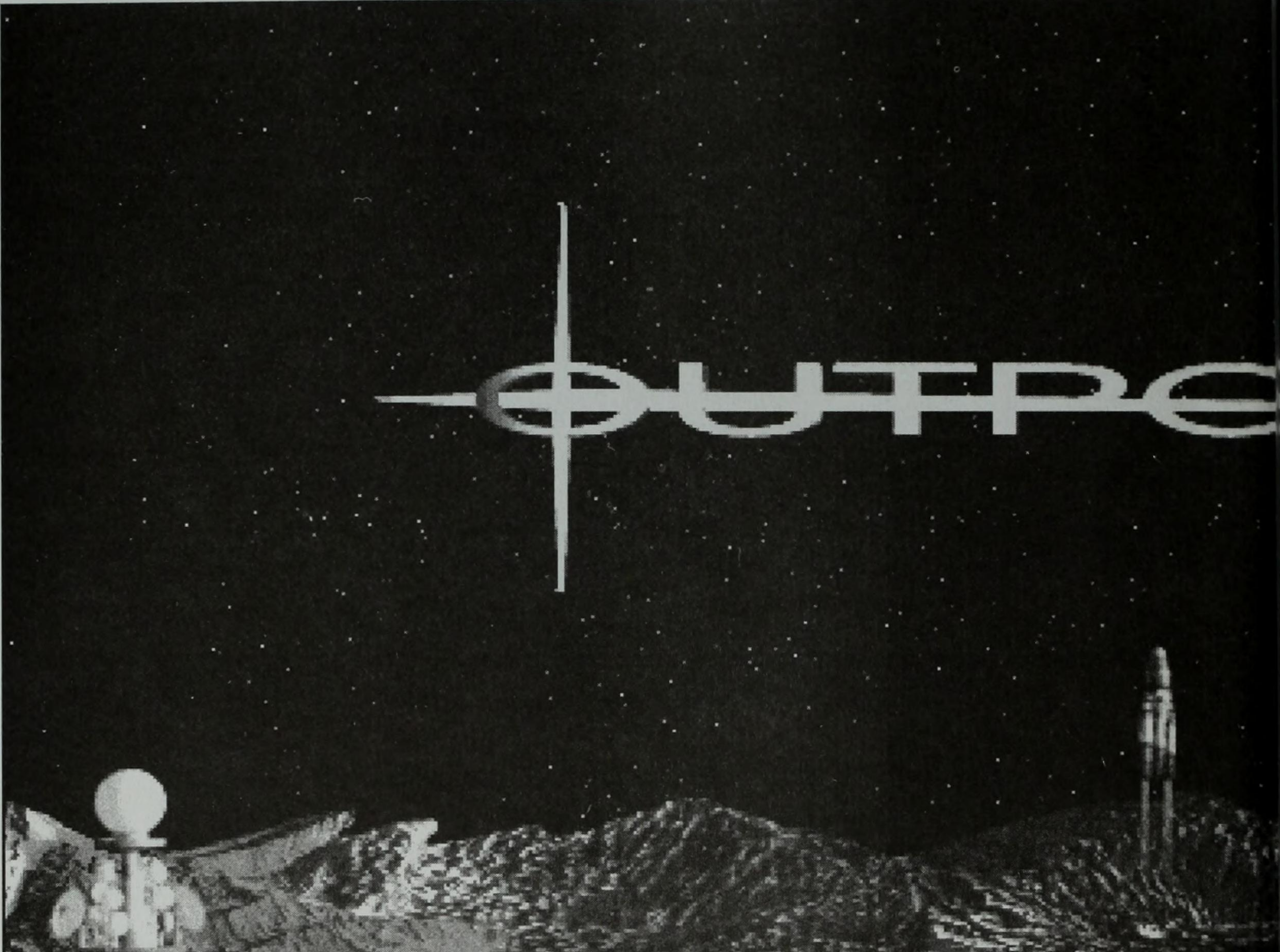


Figure 18-1 A successful colony

18

Managing the World

The history of man is a graveyard of great cultures that came to catastrophic ends because of their incapacity for planned, rational, voluntary reaction to challenge.

Erich Fromm

The challenge of colony management is similar to that of managing a struggling major corporation. People are reduced to numbers, managers carry out decisions from above, strategic production decisions must be made, competitors lurk around every corner, and a profitable balance sheet is the goal. In the case of *Outpost*, the profitable balance sheet is a civilization that can survive the destruction of Earth, leaving the cradle behind for adulthood among the stars.

This chapter focuses on methods for managing your planet. We'll take a brief look at population growth, the evolution of your colonists, how to handle emergencies, how to delegate authority to reduce your responsibilities, and how to lead your colonists into the future.

Survival of the Species

What does it take to single-handedly save the human race? Guts, brains, and an optimistic point of view that can inspire human colonists to renewed efforts at survival. If you don't have any of the traits I just mentioned, you can save the human race by buying this book. Is that an unabashed plug, or what? Having read this far, I can presume you're already among that elite group of book buyers. The key to saving civilization is knowing far more about the *Outpost* simulation than the average player. This includes clever management tactics that lead to success, as well as an understanding of population growth. From humble beginnings, as depicted in Figure 18-2, successful colonies such as the one shown in Figure 18-1 can grow.

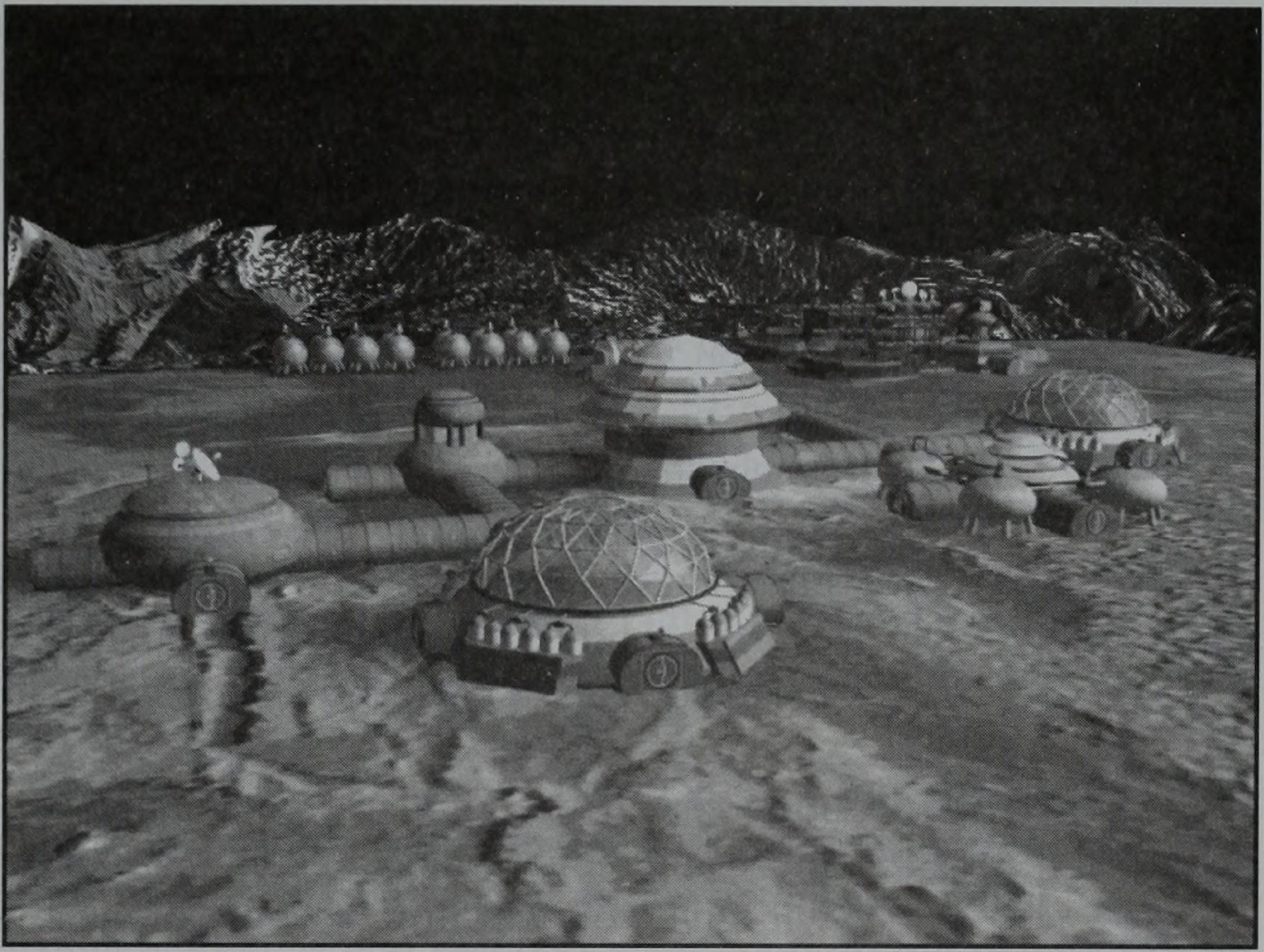
Population Growth Model

I won't go into detail, but there are certain things I can tell you about the *Outpost* population growth model. Note that whenever I refer to periods of "years," I'm referring to a special translation of 12 game turns equaling 1 Earth year, which applies only to the population growth model. No other part of the *Outpost* model uses such a convenient translation of game turns into consistent time units.

The population is divided into five groups based on the biological ages of the colonists on their arrival at the new planet: infants, a period that lasts for 3 years from birth; students, a period that lasts for 18 years; workers, a period that lasts for 19 years and includes the childbearing group; scientists, a period that lasts for 35 years; and retirees, a period that lasts for 15 years.

Figure 18-2

New colony



During the first 19-year period, parents are expected to produce one child every 3.2 years, for a total of six children per couple, on the average. This birth rate drops to four children per couple once the settlement phase of the colonization has been completed. Birth and fatality rates on a planet with a low Hostility level will tend to stabilize during the fifth year of settlement, somewhere after turn 60. Birth rates can also vary according to the success of an artificial insemination program that occurs automatically within the simulation model. Medical advances can also force a dramatic change among the number of births and deaths.

Morale also has its effect on the personal lives of your digital colonists. High morale will lead to more births and fewer deaths. Low morale can lead to suicides, a higher death rate due to depression, and fewer births.

Evolution in Action

The first 60 turns on your new planet will be the worst for your colonists. Not only do you have to build all the basic components of a strong colony, but you have to deal with a hostile environment as well. The fatality rate during this major construction phase will be high, but a tougher breed of colonist will endure the hardships to emerge as a new form of human that can deal with almost anything. The weakest members of the population, young and old, will die. Workers exposed to construction accidents will die. Morale will drop when a death occurs, but it will also rise when a birth occurs. Reproduction will happen at a tremendous pace as the colonists respond to the threat of a hostile planet and the need to keep the human race alive.

When the mortality and birth rates have stabilized at a lower level, plans for long-term colony growth can begin. At this point, it helps to have decided whether you wish to concentrate on building one massive colony or several smaller ones. Both have their advantages, and these points are considered in Chapter 20. However, just because population growth has normalized, that doesn't mean you can sit back and rest on your laurels.

Handling Emergencies

Emergencies are going to occur, forcing you to respond in an organized and rapid fashion. Keeping the appropriate satellites in orbit will give you warning of your colony's impending doom from natural events, giving you enough time to evacuate your colonists underground. Other events won't be so predictable, striking without warning to ruin your carefully prepared plans for colony expansion. A major blunder in any of these situations could destroy your colony. Hostile planets tend to be unforgiving when you make mistakes.

If you want to play it as a realistic emergency, you won't wimp out and save the game before you respond to the situation. The game is still turn based, so nothing will happen without giving you enough time to think about it and respond with an appropriate plan of action. If you want to save the game state before the disaster gets too far, and poke the simulation different ways to see how it will respond, that's a different matter. Just remember that the entire colonist population is watching your every move.

Crisis Management

The colonists will keep a close watch on how you respond to a crisis situation. The newspaper will report your clever management of an emergency, as well as describing the details of your major blunders. Morale will fluctuate in response to your handling of these situations. The basic strategy for dealing with a crisis is to gather information, act fast, and bury your mistakes. A dead population can't get depressed. Of course, they can't do any work either, but at least they won't turn the rest of the colonists against you. And whatever you do, don't let a panic break out to send morale plummeting, as it would in the case of a plague outbreak.

Plague Management

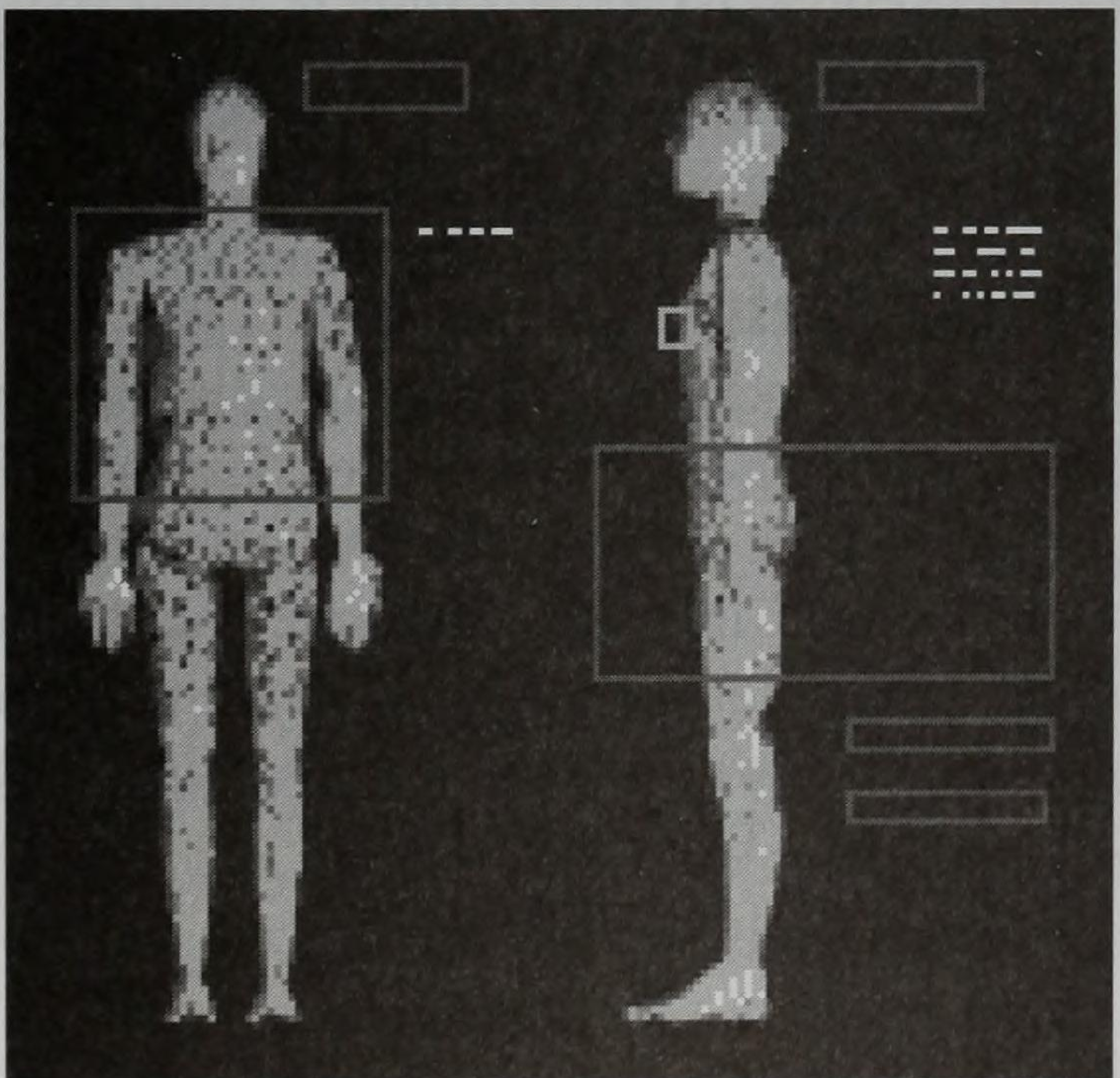
When you start hearing reports of an outbreak of plague in your colony, you have about 20 turns in which to respond to the threat. If your scientists haven't discovered the alien virus cure, you may be out of luck if they aren't performing that kind of medical research. The symbol for medical research is shown in Figure 18-3. The existence of a Medical Facility will slow the spread of the plague, doubling the time you have to respond to about 40 turns. This isn't much time, so you'd better use it wisely. Respond to newspaper interviews with polite confidence to show the populace you have the situation in hand.

Monorail connections between your colonies can spread the plague. If you don't want it to hop on a monorail and infect another group of colonists, bulldoze a section of the monorail line near the plague colony. If you respond soon enough, the plague can be isolated so that only one colony is affected.

As discussed in Chapter 20, you may wish to extend your monorail line to the rebel colony if the plague shows up. This biological warfare tactic is sneaky and underhanded, but it's a great way to get revenge.

Figure 18-3

Medical research symbol



Evacuation: Knowing When to Hide

Although your surface structures are heavily shielded to cope with the individual planetary environments, situations will occur in which the safest course of action is to hide. Each of your underground levels has at least 100 feet of dirt between it and the next level. You'll find yourself growing very fond of that dirt when the intense radiation from a solar flare bathes the surface of the planet…assuming you're clever enough to evacuate the surface population before the flare arrives.

Surface factory production will cease during an evacuation period of two turns, after which it will be safe for your colonists to return to the surface. Your colonists aren't stupid, so one warning from you is all they need to abandon the surface. If you don't tell them to evacuate, many of them will die during the event, some will linger for a few days before expiring, and everyone will think you're a jerk. Morale will plummet. Factory production will drop. Research progress will slow down. Your hair will fall out. Okay, maybe I'm exaggerating a bit on that last one, but you should understand that an evacuation is a serious matter.

If you have a weather satellite in orbit, your artificial intelligence (AI) adviser will warn you of impending solar flares, dust storms, electrical storms, and other large-scale weather phenomena. Without this warning, you'll just have to be lucky to avoid suffering damage from these planetary events. Meteorite strikes, earthquakes, volcanic eruptions, and a variety of other nasty events can also occur without warning.

You may be wondering, on a scale of 1 to 10, how often these life-threatening natural events may occur on each type of planet. Well, you've come to the right place. See Table 18-1.

Special Units

You have special teams at your disposal whose sole purpose in life is to respond to emergencies. The DIRT Facility houses a group for immediate response to any colony disaster. The engineering team housed in the Command Facility handles minor repairs within the colony, so you might think of them more as a cleanup and repair crew for small jobs that don't require the heavyweight attention of a DIRT team.

Table 18-1 Probability of Life-Threatening Natural Event, by Planet Type[a]

Type of Planet	Solar Flare	Meteorite Strike	Earthquake	Volcanic Eruption	Wind Storm	Sand Storm	Electrical Storm
Mercury class	10	7	7	2	0	0	0
Venus class	6	1	6	7	4	0	3
Mars class	2	4	5	0	5	4	3
Earth's Moon class	4	7	3	0	0	0	0
Phobos class	3	7	3	2	0	0	0
Ceres class asteroid	5	7	2	0	0	0	0
Pluto class	0	5	3	0	0	0	0

[a] Entries represent the probability of occurrence on a scale of 1 to 10.

DIRT

The Disaster Instant Response Team (DIRT) Facility minimizes damage from unexpected colony events that damage your structures. These events range from meteorite strikes to laboratory explosions. Because the environment is hostile and bad things happen fast, the DIRT response area is limited. On average, the DIRT Facility can protect structures in a five-tile radius around itself. The closer a building is to a DIRT team, the better are its chances of surviving disasters with minimal damage. As you can see, it's a good idea to have several DIRT Facilities placed around a colony. The DIRT is your friend. Depend on the DIRT.

Engineers

Housed at the Command Facility, the Engineering team is a group of clever individuals with a complete set of tools. Where the DIRT team fixes the big problems, the engineering team fixes the leaky faucets and the plugged toilets of the colony. Although they resent the fact that the DIRT teams get all the attention, the engineers never complain about the poor working conditions of their unglamorous occupation.

When they're applied to a colony structure, engineers will repair everything that appears to be wrong with it. This maintenance activity keeps the structure operating in a reliable fashion for a longer period of time, resetting the internal rate of decay for that building to the state it was in when it was constructed.

From Micromanagement to Macromanagement: Delegating to Win

When you have developed your computer science research to the point at which multiple AI managers are possible, you have the option of switching from micromanagement to a macromanagement level of operation.

At the micromanagement level, starting from the beginning of the game, you must involve yourself with every tiny detail of colony operations. This can be a logistical nightmare when the colony grows to a large size, or when you're dealing with several different colonies. A single game turn could take hours. If you like that sort of thing, it's your game and you can play it any way you want, but if you're more of an executive manager, you may prefer to delegate some of your responsibilities to others who can handle the small stuff.

At the macromanagement level, you can assign your AI managers to administrative tasks so that you don't have to deal with every dripping faucet or floor mopping job in every colony. A list of general directions and priorities can be assigned to the AI manager of an individual colony, then the AI will execute those tasks for you over a long period of time, assuming that colony doesn't run out of resources while carrying out your grand plan.

For example, you may want Egbert, the AI that manages Bob's Colony, to specialize the function of that colony through an intensive Agricultural Dome-building program. You assign Egbert the task, then come back 200 turns later to find that Agricultural Domes have taken over that section of the planet. This is a wonderful thing, so you connect Bob's Colony to your other colonies by monorail and use it as the food production capital of your planet. This example assumes that Egbert is a stable AI personality. If he's nuts, you might come back 200 turns later to find that Bob's Colony is the Communications Tower capital of the world.

With macromanagement capability, the ability to specialize an individual colony's function becomes a major strategy in your conquest of the planet. With the basic necessities of life and connections to a few good mines, a colony can become a factory production center, a food center, a commercial center, a recycling center, a medical center, a power center, a smelting center, or any other kind of center, except maybe off-center. You can create a bedroom community, a university district, or a police state. As long as these specialized colonies are connected by trucking or a good monorail network, and you have multiple AI managers to assist you in the administration of colony functions, then you have a powerful method of management available to outwit your competition and dominate the planet.

One big point to remember is that you can delegate authority to your multiple AI managers, but you're the one who will get the blame if they fail or make major blunders.

The Advancement of Civilization

With careful management, your civilization will advance. With research into systems analysis and efficiency improvements in factory production and management, combined with the careful development of your colony during the settlement phase, your entire group of colonists will demonstrate enough remarkable cleverness to qualify for civilization advancement. When this happens, morale will improve and a new breed of efficient structure will become available for construction. These new buildings are efficient replacements for your older technology.

With advancement, your colonists will also be more likely to trust your judgment in administrative manners. It won't cause the newspaper editor to show you any more respect, but that's just another way that *Outpost* simulates real life. Some things never change.

This chapter has provided you with numerous management tips and a shallow understanding of the population growth model. It has also introduced you to the the strategy of specialized colonization, in which each colony serves a specific function for the common good.

The next chapter will guide you into the dark digital forests within the simulation, poking around among the electrons to reveal the secrets lurking within the mathematical model. For your own safety, remember that the simulation can smell fear, so try to remain calm as you tiptoe through the next few pages.

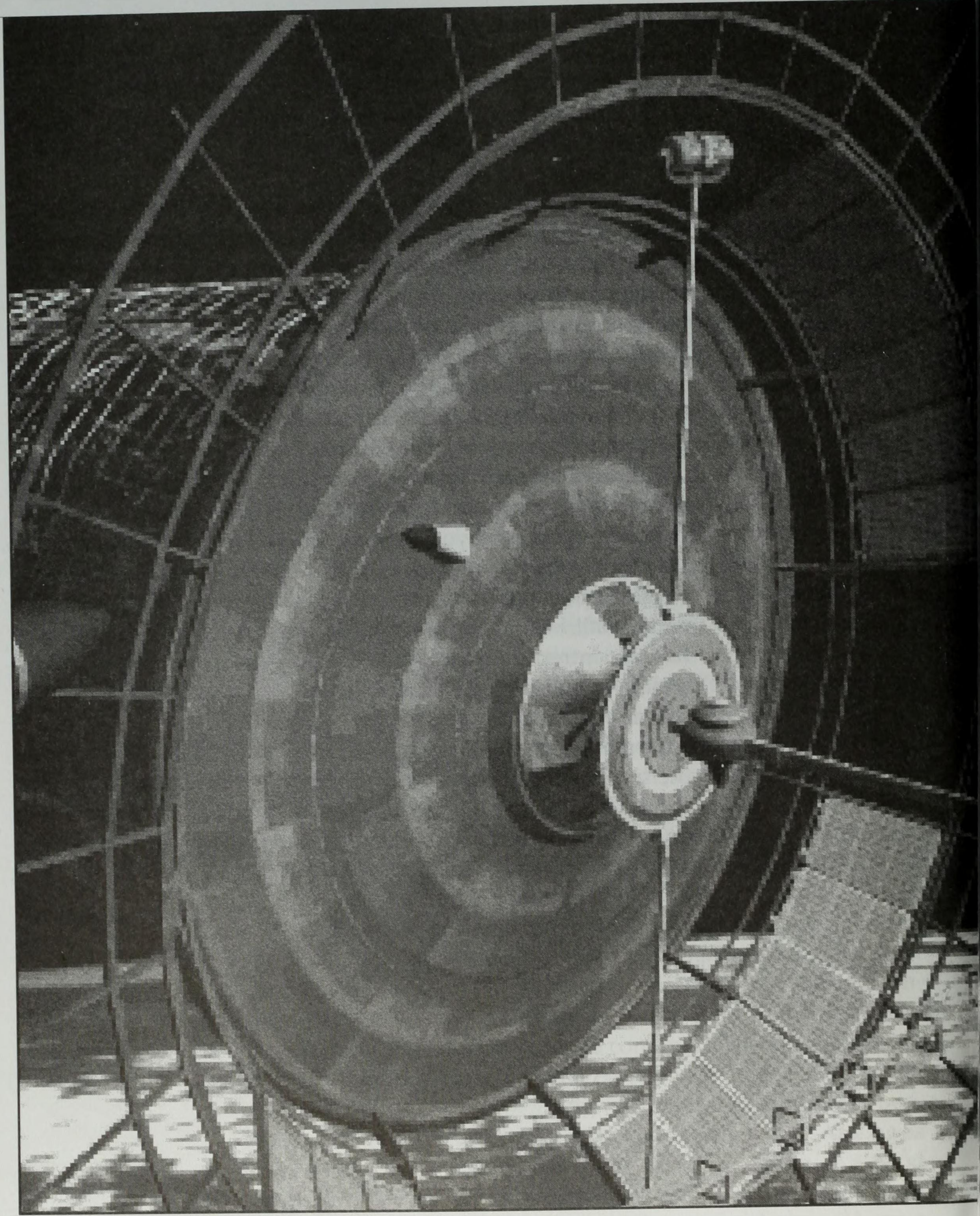
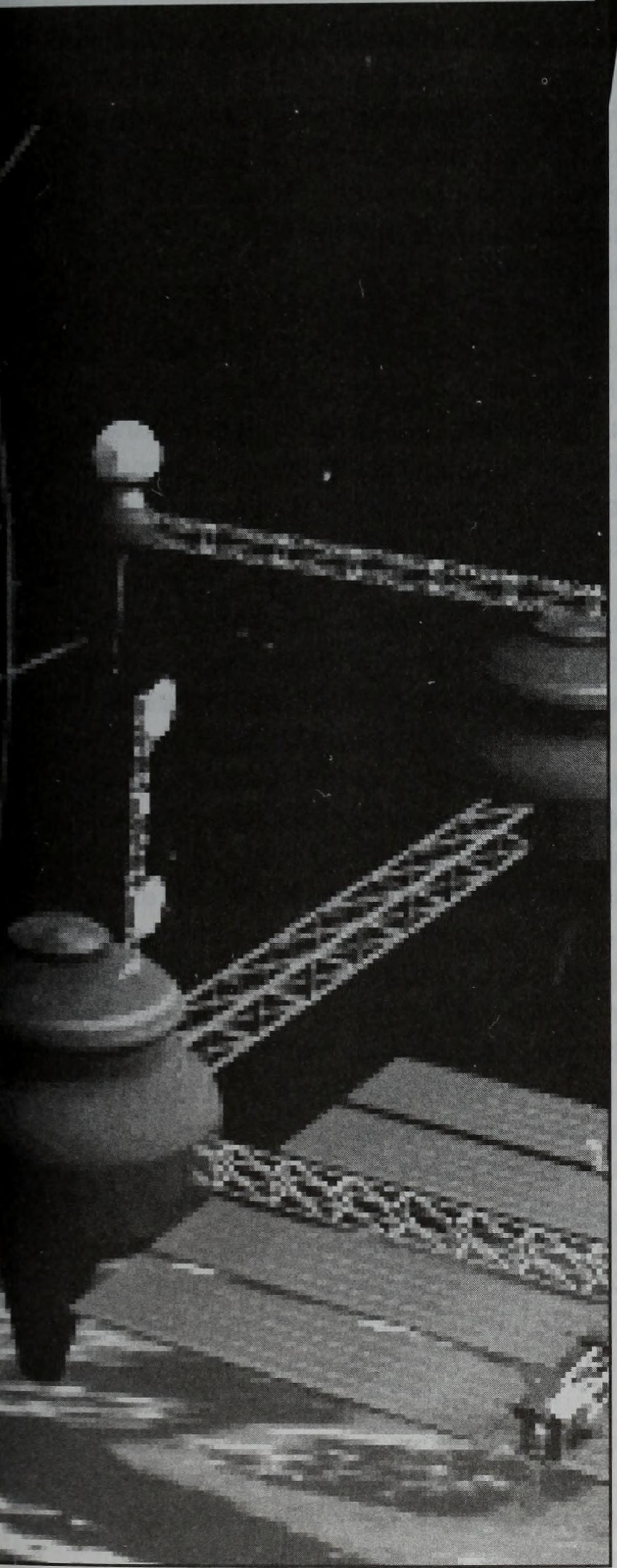


Figure 19-1 Starship under construction



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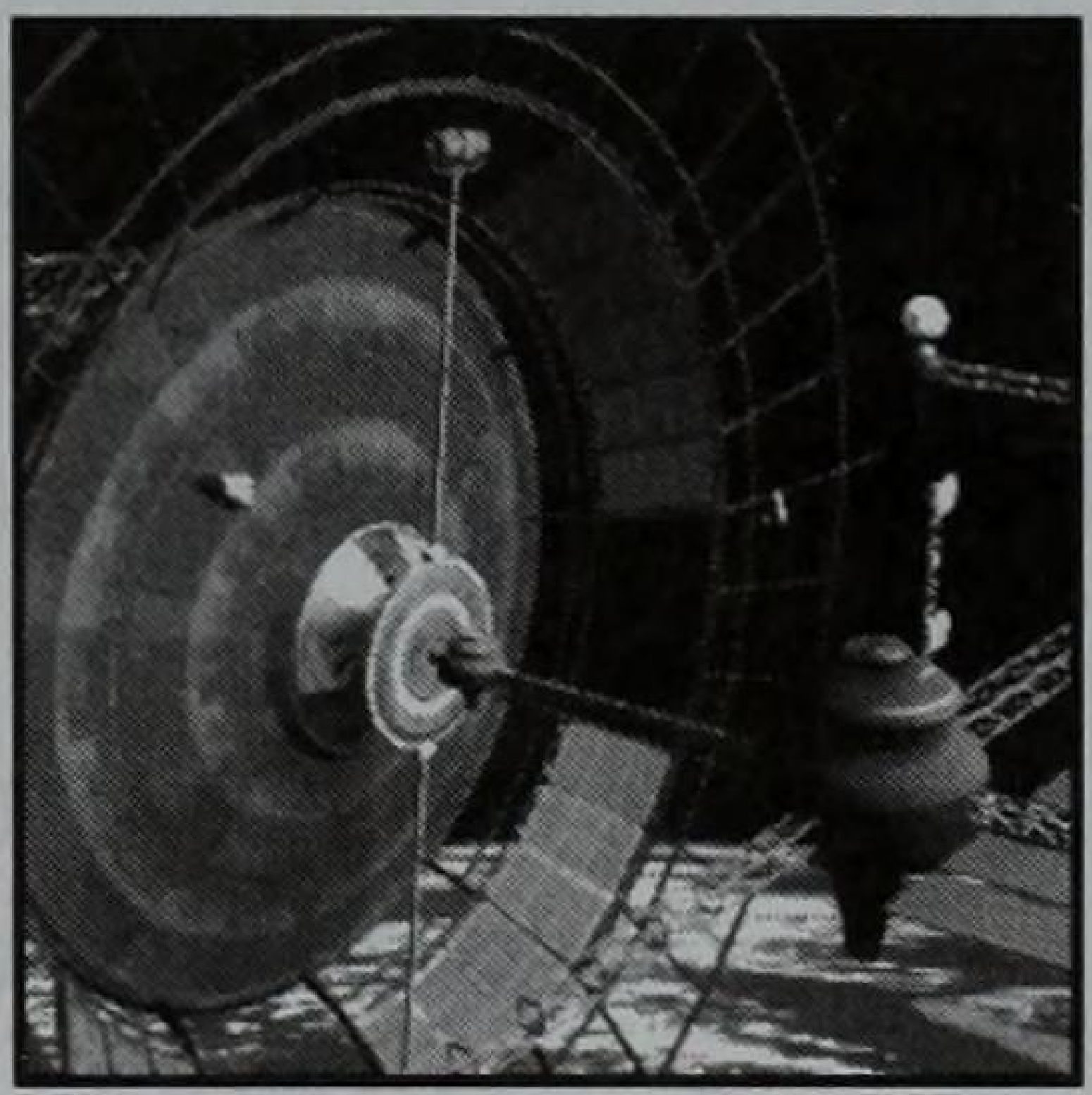


Inner Workings of the Simulation

God not only plays with dice. He sometimes

throws them where they can't be seen.

Stephen Hawking

If you want to know more about what makes *Outpost* tick, this is the chapter for you. Because I'll be discussing the guts of the simulation, most of this information is internal to the game and not available to the player through normal means. If you'd prefer to maintain a sense of mystery about how the mathematical model operates, then skip this chapter. This is your final warning. We don't need your kind around here.

An Overview of the Mathematical Model

Now that I've warned and enticed you, I'm still not going to tell you everything about the details of the simulation. Some things should remain a mystery. When you're old enough, you learn that the Easter Bunny and Santa Claus are just figments of someone's fevered imagination, and this provides you with some security in the knowledge that giant rodents and strange men won't be coming down the chimney into your house late at night. If you're like me, you probably wondered how all these fantastic creatures kept getting into the house in the first place. The idea of the Tooth Fairy still gives me the willies. Of course, when I learned the truth about these characters, I sank into a mild depression from the news, perhaps realizing that my childhood was slipping away. So, this is my philosophy regarding the *Outpost* model: I'll tell you enough to make you feel secure, but I don't want you to get depressed.

The programming was implemented in three stages that allowed thorough testing of the model before it became too complicated to debug. The first stage got the structures and major formulas running their numbers through the model so that we could watch for results that were wildly inaccurate. When that phase had stabilized, we added the internal "artificial intelligence" that operates the rebel colony. The rebel colony functions in such a way that it can have quite an impact on the player's colonies over time, but debugging was easier when we knew that the player's colony numbers were running properly through the model.

The third stage of development implemented the "chaos seed," designed to make the whole simulation appear more human by introducing number variations of the type that occur in any human system of activity. For example, human moods vary each day, so factory production is not constant when it depends on humans to operate the equipment. Instead of producing 10 Snappy Widgets per hour, someone who's having a bad day may produce only 7 Snappy Widgets per hour, thereby introducing the human element to a mechanized factory system. This can be annoying when your survival depends on that factory production, but organic life forms are unpredictable by their nature.

As with any simulation, effects on the model are interconnected in such a way that if you poke it in one place, you're going to get a result somewhere else. In *Outpost*, the major modifier that ties everything in the model together is the Morale value, which ranges from 0 to 1000. Morale is affected by almost everything in an indirect way, and by a couple of things that can be manipulated by the player in a direct way. The level of morale at the end of one turn has a direct effect on calculations during the next turn. As a general rule, keeping the morale of the colonists high will keep your morale high, so it's useful for you to learn how to run your dog-and-pony show to keep those people happy.

Life Would Be So Much Simpler If It Could Be Condensed to 200K

When you indicate that you've completed a turn, methods described in Chapter 5 or in the game manual, the calculations begin and the turn is processed. Player actions, including robot movement, structure building, and research choices, are considered and compared against available power, population, and resources. Movement takes place, population levels increase or decrease, mined resources increase or decrease, factory production occurs, and power levels change.

By factoring in the effects of the hostile planetary environment and any disasters that may have occurred during that turn, a preliminary value for morale is calculated. This value is modified by the presence of Police Stations, luxury items, Recreational Facilities, and Residential Population Density. A final value for morale is calculated and carried over to affect Production and Research levels during the next turn.

Formula Variables and Modifiers

Formula variables and modifiers are some of the dynamic values in the mathematical model. The indicated point values for some of these items are internal to the model, so you wouldn't normally see them in this form. This section is only for those who are unafraid to confront the truth inside the simulation.

Morale

The Morale value is carried over from the last turn and has a direct modifying effect on production and research levels for the current turn. Morale has a range of 0 to 1,000, with a starting value of 600. The following is a list of effects of morale on overall factory production and research progress.

Production levels are cut by 50 percent if Morale = 0 to 249
Production levels are cut by 25 percent if Morale = 250 to 449
Production levels are unaffected if Morale = 450 to 549
Production levels are increased by 25 percent if Morale = 550 to 749 (starting at 600)
Production levels are increased by 50 percent if Morale = 750 to 1,000
Research progress is cut by 50 percent if Morale = 0 to 249
Research progress is cut by 25 percent if Morale = 250 to 449
Research progress is unaffected if Morale = 450 to 549
Research progress is increased by 25 percent if Morale = 550 to 749 (starting at 600)
Research progress is increased by 50 percent if Morale = 750 to 1,000

Luxury Pool/Commercial Distribution

The factories that create luxury goods typically generate luxury at the rate of 1 unit per turn. These units are deposited in the luxury "pool" (the same way other resources are handled). Commercial structures automatically draw from this pool at the rate of 1 Luxury unit per turn per Commercial structure as long as the pool has Luxury units in it. The Commercial structure distributes the luxury goods, so it also adds 1 point to the Morale value of the population.

Morale Modifiers per Structure per Colony

The following structures have a direct effect on the Morale value during the calculation phase after a turn has been completed.

Commercial/Luxury

As long as a Commercial structure is distributing luxury goods, it adds 1 point per turn to the Morale value of the population.

SPEW Facility

By recycling the waste products of the colony, each SPEW (Sewage Processing and Environmental Waste) Facility adds 1 point per turn to the Morale value of the population.

Nanotechnology Facility

Because production becomes much easier with a Nanotechnology Facility, each structure adds 1 point per turn to the Morale value of the population.

Agricultural Dome

The presence of an Agricultural Dome, the source of growing food, adds 1 point per turn to the Morale value of the population.

Hot Laboratory

Because the population is nervous about working in or around a Hot Laboratory, each structure subtracts 1 point per turn from the Morale value of the population.

Terraforming Facility

Because it generates a breathable atmosphere for the entire planet, the presence of each Terraforming Facility adds 5 points per turn to the Morale value of the population.

DIRT Facility

By giving the population a sense of security and preparedness, each DIRT (Disaster Instant Response Team) Facility adds 1 point per turn to the Morale value of the population.

Park/Reservoir

The presence of a Park adds 1 point to the Morale value of the population.

Recreational Facility

The presence of a Recreational Facility adds 1 point to the Morale value of the population.

Engineering

An active Engineering team will add 1 point to the Morale value of the population every turn. Inactive teams have no effect.

Police

The local police force, whether human or robot, has an attitude the player can select. The two choices are Benevolent (+1 Morale) or Hostile (-1 Morale) per structure per turn, which has a direct effect on the Morale value of the population. If the player has one Benevolent Police station and one Hostile Police station, there will be no effect on morale because the two structures will cancel each other out.

Red Light District

The presence of a Red Light District adds 2 points to the Morale value of the population.

General Morale Modifiers per Colony

General morale modifiers exert effects that are not a direct result of individual tile structures.

Residential Population Density

While there is surplus housing for the current population, 1 point will be added to the Morale value. Insufficient housing will subtract 1 point per turn from the Morale value. Sufficient housing has no effect. If there is no housing, 20 points per turn are subtracted from the Morale value.

Crime

The Crime level range is 0 to 100, with a starting value of 0. One point is subtracted from the Morale value for every 10 points' worth of Crime level. For example, if the Crime level is at 40, you would subtract 4 points from the overall Morale value. The Red Light District and Police stations have a direct effect on the Crime level (and the subsequent morale for the next turn), as do the Residential Population Density, Educational level, and Morale level.

Residential Population Density has no effect on Crime or Morale if = 25
Residential Population Density > 25 = +1 Crime and -1 Morale
Residential Population Density < 25 = 0 Crime and +1 Morale
Red Light District = +2 Morale and -1 Crime
Police (Benevolent) = +1 Morale and reduce Crime by half locally
Police (Hostile) = -1 Morale and reduce Crime to zero locally
Educational level > 50 = -1 Crime
Educational level = 50 = No effect on Crime
Educational level < 50 = +1 Crime
Morale = 0 to 249 = +2 Crime
Morale = 250 to 449 = +1 Crime
Morale = 450 to 549 = No effect on Crime
Morale = 550 to 749 = -1 Crime (starting value, 600)
Morale = 750 to 1000 = -2 Crime

Industrial Capacity

If all factory structures are operating at full capacity, 1 point will be added to the level of morale per turn. This means 1 cumulative point per turn, not per factory per turn.

Resource Production

If all factory structures are operating at full capacity and there is a surplus of resources at the end of the turn, 1 point will be added to the level of morale per turn.

Environmental Pollution

If there are factories producing negative environmental effects, a factory attribute, for a cumulative negative total of 2 to 4, subtract 1 from the Morale value per turn. If the negative total is 5 to 10, subtract 2 from the Morale value per turn. If the negative total is greater than 10, subtract 3 from the Morale value per turn. Environmental effects range from 0 to 100, starting at 100. Note that SPEW Facilities have a +1 Morale and +1 Environmental effect.

Educational Level

An Educational level of 50, the starting value, has no effect on morale. An Educational level > 50 will add 1 point to Morale each turn that the value is greater than 50. An Educational Level < 50 will subtract 1 point from the Morale value each turn that the value is less than 50. The University and underground Laboratory structures have a direct effect on the Educational level.

Planetary Hostility Rating

With a range from 1 to 12, the Hostility rating has a constant effect on morale. A Hostility rating of 1 = no effect, but every Hostility point greater than 1 will have an equal number of points subtracted from the Morale value each turn. This Hostility rating can change only through the successful completion of terraforming, which will reduce the rating to 1.

Disasters

Each disaster, such as a meteorite strike, solar flare, or plague, will subtract 10 points from the Morale value of the affected colony on the turn following the disaster event, allowing time for the news to spread.

The Morale Formula

With a few modifications, this is the Morale formula as it operates in the *Outpost* mathematical model. Variable definitions are given in sequence, along with each variable's effect on the Morale formula. Other game factors affect results after this formula is processed.

Note that M is the current Morale value (ranges from 0 to 1,000), and that $M = 600$ at game start.

COMADD = # of working Commercial structures distributing luxury	$M = M + \text{COMADD}$
SPEWADD = # of working SPEW structures	$M = M + \text{SPEWADD}$
NANOADD = # of working Nanotechnology structures	$M = M + \text{NANOADD}$
AGADD = # of working Agricultural Dome structures	$M = M + \text{AGADD}$
LABSUB = # of working surface Hot Laboratory structures	$M = M - \text{LABSUB}$
TERRADD = # of working Terraforming structures × 5	$M = M + \text{TERRADD}$
DIRTADD = # of working DIRT structures	$M = M + \text{DIRTADD}$
PARKADD = # of Park structures	$M = M + \text{PARKADD}$
RECADD = # of Recreational structures	$M = M + \text{RECADD}$
ENGADD = # of active Engineering teams	$M = M + \text{ENGADD}$
POLBEN = # of Benevolent Police structures	
POLFAS = # of Hostile Police structures	
POLADD = # of POLBEN	$M = M + \text{POLADD}$
POLSUB = # of POLFAS	$M = M - \text{POLSUB}$
REDADD = # of Red Light Districts × 2	$M = M + \text{REDADD}$
RESREQUIRED = CURRENTPOP/25	
RESTILES = SEEDTILE + RESIDENTIAL	
RESPOPDEN = RESREQUIRED/RESTILES	
RESPOPDEN = 1 (Housing = Current Pop.)	$M = M + 0$
RESPOPDEN < 1 (Surplus Housing)	$M = M + 1$
RESPOPDEN > 1 (Insufficient Housing)	$M = M - 1$

RESPOPDEN = 0 (No Housing or SEED)	$M = M - 20$
CRIMECHANGE = CRIMELEVEL/10	$M = M$ - CRIMECHANGE
INDUSTRYCAP = # of factory structures/# working at full capacity	
INDUSTRYCAP = 1	$M = M + 1$
ELSE	$M = M + 0$
If INDUSTRYCAP = 1 and there is a surplus of resources that turn	$M = M + 1$
ENVIROSUB = total of negative environmental effects	
ENVIROSUB = 0 or 1	$M = M + 0$
ENVIROSUB = 2 to 4	$M = M - 1$
ENVIROSUB = 5 to 10	$M = M - 2$
ENVIROSUB > 10	$M = M - 3$
EDLEVEL = total Educational level	
EDLEVEL + 50	$M = M + 0$
EDLEVEL > 50	$M = M + 1$
EDLEVEL < 50	$M = M - 1$
HOSTILITY = Hostility of planetary environment (constant)	
HOSTILITY = 1	$M = M + 0$
HOSTILITY > 1	$M = M$ - HOSTILITY
DISASTER	$M = M - 10$

The final *M* value is then carried over to the next turn to modify Production and Research levels. Population level changes are also modified by morale during the current turn.

Although there are numerous smaller calculations that occur each turn, this formula gives you the basic idea behind the primary model.

Your Opponent

I won't say too much about your artificially intelligent opponent, the rebel colony. My computer science degree is in artificial intelligence, so I hesitate to use the term in regard to computer games, although it has become a customary buzzword during the last few years. A true AI opponent would be thinking, learning, and adapting to your behavior, just as a human opponent would. Although I think the AI opponent in *Outpost* is terribly clever in design, and is smart enough to base some of its decisions on your actions, making use of your human brain to solve some of its problems, it is a far cry from a true AI system.

The difficulty level you choose at the beginning of the game also determines how tough a competitor you will have in the rebel colony. If you want easy competition, you will find it easy to outfox the AI. If you want difficult competition, the AI will be much more subtle in its course of action. Keep in mind that you might want the rebel colony to prosper so that you can lure those colonists over to your colony, then take over the abandoned rebel colony. This strategy is discussed in Chapter 20.

It's Only a Model

Yes, it's only a mathematical model, a simulation of a complex system in reality that has been simplified enough for a personal computer. However, you will find that a complex, well-developed game of *Outpost* will start to exhibit a high-level process known as *emergent behavior*. This is a biological and philosophical theory used to describe simple systems of interlocking processes that generate unpredictable results of a higher order.

Artificial life researchers expanded the definition of emergent behavior to include *cellular automata* on computers. Cellular automata are imaginary mechanisms, but when they're simulated on a computer, they exhibit the same behaviors as natural physical systems. By modeling a lot of simple systems in *Outpost*, such as the operations of the colony and its structures, the interactions create a whole greater than the sum of the parts.

Human evolution is an example of emergent behavior, which is not a software bug, but a blending of the genes of simple organisms to generate more advanced forms of those organisms. This doesn't always happen, especially when someone has been peeing in the gene pool, but when it does, evolution takes one step further. There are other systems that exhibit emergent behavior, such as people in grocery stores. Nobody enjoys or plans on standing in long lines while waiting to pay for their groceries, but this is what happens when you get more than a few people into the store. Economic recessions aren't planned, and neither are economic recoveries, but they happen anyway because small economic effects can snowball into a large impact on the whole economic system.

This unpredictability of behavior made the playtesting of *Outpost* much more interesting than a standard Sierra game, because we had to determine whether an unexpected result was something clever generated by the simulation, as opposed to a bug we had to hunt down and kill in the source code of the program. Keep this in mind when your entire colony population decides to defect to the rebel colony. It's nothing personal. Emergent behavior also makes a wonderful excuse in case we missed a bug in the game. We can always say, "It's not a programming bug. It's emergent behavior!"

This chapter has given you far more information than you ever wanted about the inner workings of the *Outpost* simulation model. Maybe now you have a better idea about what happens while each of your game turns is being processed. The next chapter will plunge headlong into the deep and dangerous waters of *Outpost* strategies for success, and my personal favorite: strategies for mayhem.

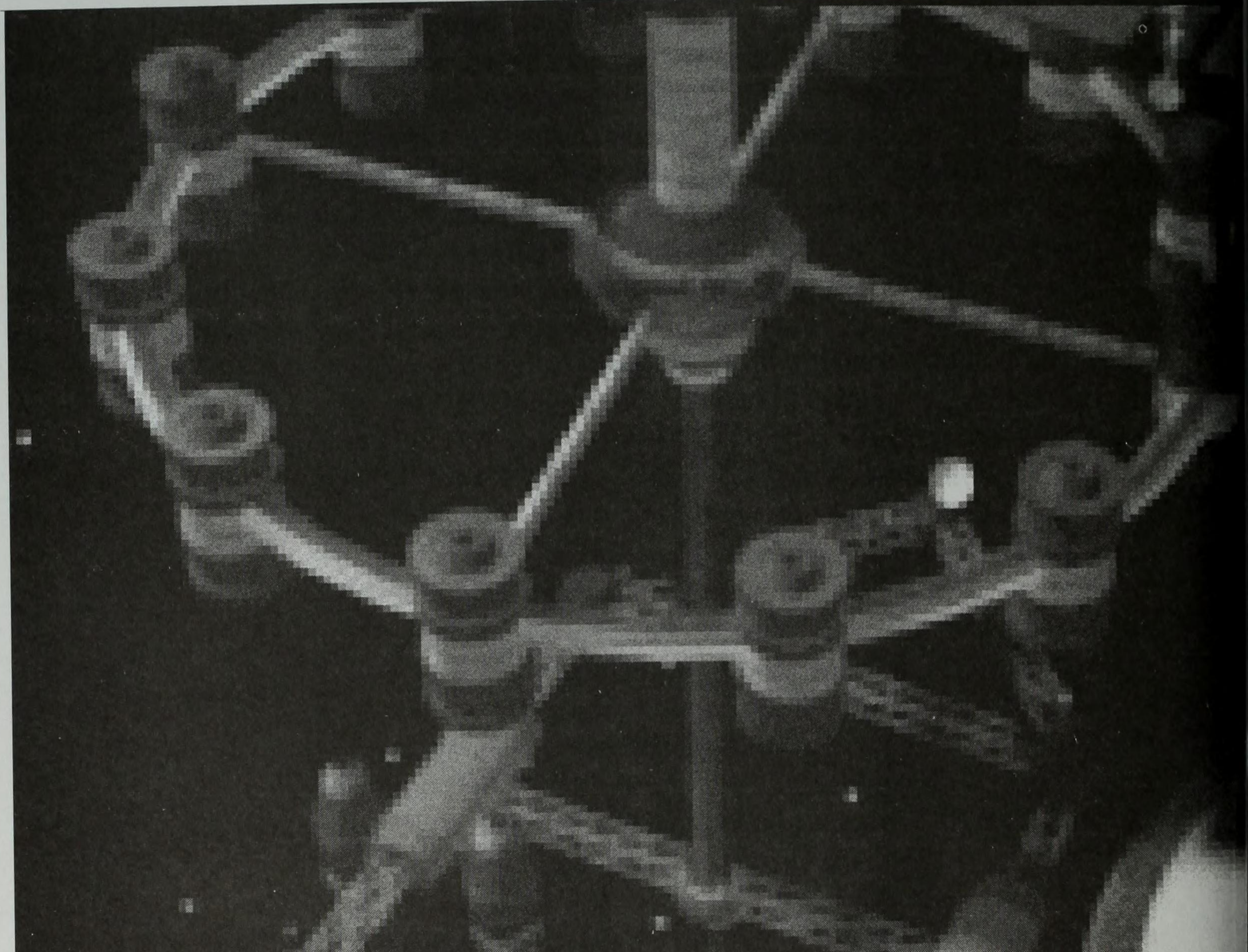
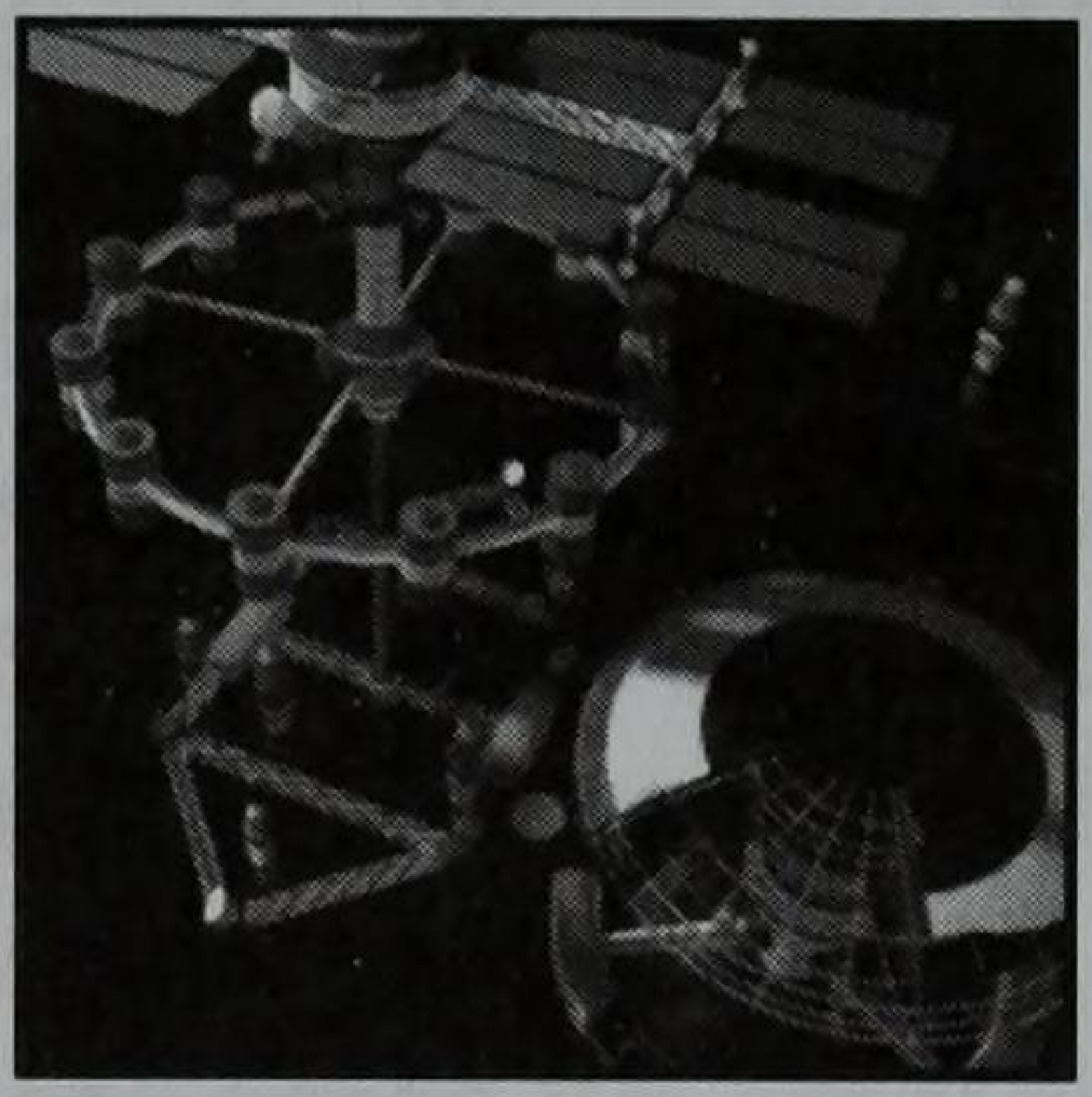


Figure 20-1 Second starship under construction

20



Strategies

I didn't do it, nobody saw me do it, you can't prove anything.

Bart Simpson, *The Simpsons*

During the development of the simulation, I had certain preconceived assumptions in mind regarding how the colony would work. These assumptions were tested on paper, the design was solidified, then art and programming started. Over time, these assumptions were modified to make the mathematical model more realistic with regard to human factors. With most of the programming done, I started thinking about new strategies that could affect the simulation in "unapproved" ways, such as letting crime run rampant so that the player could build a criminal empire, or using biological warfare by sending an outbreak of plague over to the rebel colonists. These are possibilities inherent in the model, even though we didn't set out to program it that way.

This chapter looks at tips for successful colony development, keeping your colonists happy, controlling the end points of the game, tactical decisions, and unorthodox strategies you can use to "trick" the simulation into behaving in ways different than you might expect.

A Happy Planet Makes a Dull Life

A good disaster can really liven up a game you had all mapped out in advance. The dynamics of the simulation allow you to subvert your own plans to cause problems for your colony and for yourself. If you know the proper way to do something, try thinking in reverse and performing the opposite action. If morale is high, try diverting your resources away from food production for a while to build a Police Station for beating the public into submission. If things are going too well, and it seems you can do no wrong, push the Armageddon button (Ctrl - F10) to force a disaster of your choosing on the poor sods in your colony. The Armageddon button, and other hidden features, are described in more detail in Chapter 26.

Manipulating the Media

If you've noticed how fast morale changes in the simulation, you might have wondered how news gets around so quickly in the colony. The *Outpost Evening Star* is published frequently on an irregular schedule, but the major conduit for news and information is the colony rumor mill.

As with any small town, the local gossips make sure that everyone knows what everyone else is doing. It's one of those weird human things. People seem to have a need for that kind of information, which is why televised news does so well on Earth. So, if you turn out to be a lame administrator, everyone will know about it and there will be a corresponding drop in morale.

In many cases, you'll know what the public is thinking after the fact by the news briefs your AI adviser provides you from the *Outpost Evening Star*. But a clever politician knows that public opinion can be swayed through various means. The newspaper can be used to your benefit, showing you how your plans for manipulating the morale of the population are progressing. If your public image is bad, you can always consent to an interview.

A situation might arise where you *want* morale to drop. If you don't want to make direct changes to factory production, but you're using too many resources, you can slow production by making sure that the morale of the population drops. Maybe you can't feed or house all of your colonists properly, so you let morale drop low enough so that they start defecting to the rebel colony, where they become someone else's problem. Later on, you can bring morale back up and your colonists will return. It's an odd way to handle these situations, and it might backfire, but it's a possibility to consider if you're desperate.

When rumors are flying around, the editor of the newspaper may request an interview through your AI adviser. This is an opportunity for a direct effect on public opinion. When this happens, you have five options for responding to the request, but each response has different repercussions:

"No Comment" will cause morale to drop by 1 point. The next headline that appears in the news will usually be: "Massive Coverup in Halls of Power!"

"Make an Appointment" will delay any reaction for 10 turns, then morale will drop by 1 point and the same headline as for "No Comment" will be generated in the newspaper.

"Consent to Interview" will prompt a rise in morale of 1 point. Your gracious treatment of the editor during the interview leads to the headline: "Colony Administrator Reassures Public."

"Interview Immediately" may seem like a response that tells the editor you consider him to be an important person. However, the editor senses your desperation, so there's a 50 percent chance that morale will rise or drop by 2 points. One of two headlines will be generated in the next issue of the newspaper: "Administrator Unveils Bold Plan" or "Administrator Unveils Insane Plan."

"Generic Press Release" is another risky response, having a 50 percent chance of dropping morale by 1 or 2 points. This response tells the editor that you're afraid to talk, so the press will assume the worst. The resulting headline will be: "Administrator Confused, Colony Doomed."

The lesson you should learn from this is to consent to an interview if you don't want to get roasted in the press. If you want morale to drop, choose one of the other options.

Structure Strategy

An aggressive construction program early in the game can lead to trouble. Building must be balanced against resources, taking maintenance of existing buildings into account. New construction, shown in Figure 20-2, won't start if the resources aren't available, but what if you're building something and work stops before the structure is completed because you've run out of resources? My advice would be to bulldoze an existing structure if you have a Sewage Processing and Environmental Waste (SPEW) Facility. The materials will automatically be shipped to the SPEW Facility, adding multipurpose goo to your colony resource stockpile. The same advice holds if you can't build anything new and you need to free up some resources that are being used to maintain existing structures.

Once you know that your colonists are safe and secure with Residential units to live in, air to breathe from a Closed Habitat Atmospheric Production (CHAP) Facility, and food to eat from an

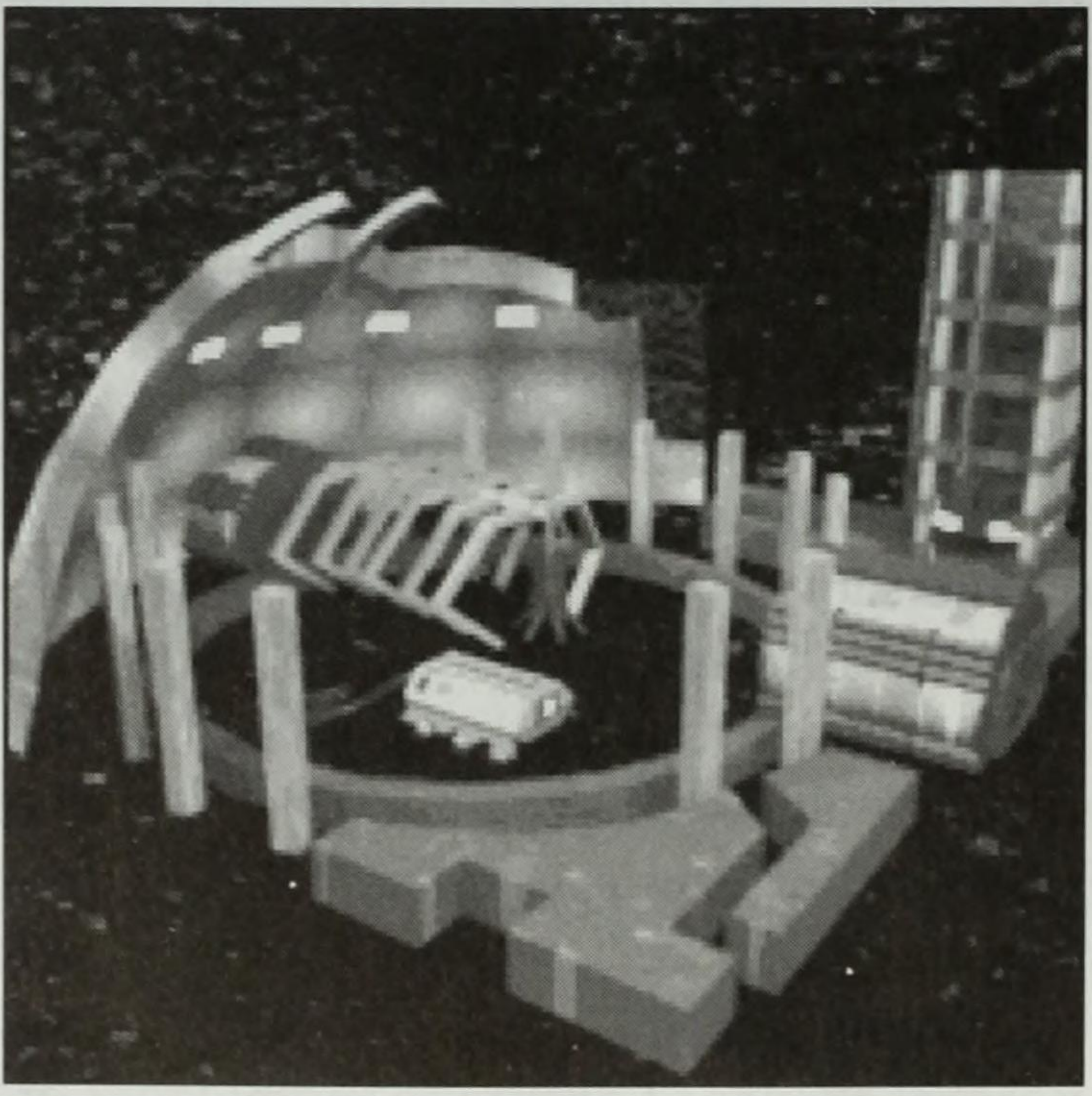


Figure 20-2

Construction site

Agricultural Dome, whip those robominers into a frenzy of activity and get those mines generating more resources for you. Build Roads to speed the process of moving mined resources to the Smelter and to the colony Storage Tanks. Build factories to produce robots and other necessary items. Pace the whole process so that your energy and resource demands don't get ahead of your ability to produce power and mined ore.

Colony Size The growth of your colony is restricted by the available power supply, mined resources, the birth and death rates of your colonists, and the morale of your population. All of the *Outpost* planets are hostile enough that their presence is felt in everything you do on the new planet, from mining to having babies. Clever administration will overcome all of these obstacles, but you must decide how you want your colony to grow on the basis of local conditions, which are different in each game.

Population Growth

Your colony is composed of people as well as structures. These digital lives are dependent on you for their survival, but they have lives of their own as well. Their moods change in response to how you're treating them, so factory production and research progress will vary over time as they do with any human system. The first colonists are quite aware that they're the last of the human species, so they'll do their best to create new members of the population. Over each 19-year period of prime parenthood possibility, the average couple is expected to have an average of six children who are above average. Some will have more, some will have less, but the need for increasing their numbers will be very strong due to their awareness of possible extinction in the face of the hostile planetary environment.

In the beginning, your colonists will also be aware of the high mortality rate among them. The new planet will claim lives before it allows more to get started. While the first year will be the worst, with about an 80 percent average death rate among the oldest members of the population, there will be gradual improvements as more structures are built and more people are living underground with some decent protection from the elements. In an effort to plan ahead, most of the colonists selected were young when they started their interstellar voyage. With their metabolisms slowed during the long trip, they didn't age as fast as they would have naturally, so most of their bodies were at a biological age of between 30 and 40 years when they arrived at the new planet.

After the colony has been established for a few years, the death rate will take a sharp drop, but the added security will also cause the birth rate to drop, so that the average parents will have only four children over a 19-year period. These numbers will vary according to the results of the artificial insemination program, which statistically affects the population growth model in the game. This program, consisting of frozen sperm and eggs collected on Earth, will also add necessary variety to the gene pool. This "gene bank" from Earth is the same as that used to preserve some extra animals beyond the few that were brought on the starship.

Thinking Big

To take advantage of the economies of scale, you can expand your colony to an enormous size, dominating the surroundings with its bulk. As with any large city, such a colony is a voracious creature, always wanting to be fed more in the way of power and resources to maintain itself. However, everything is close together, so it's cheaper to build tubes and roads to provide necessary connections.

If there's a mine in the immediate vicinity, the reduction in travel time for the resources going from the mine to the Smelter, then to the colony Storage Tanks, is fast and efficient. More police support is necessary to control crime in a large colony, but DIRT and Engineering teams have a shorter distance to travel in emergencies. Fewer Communications Towers are necessary for the control of local robots. So, thinking big has its advantages, but so does thinking small.

Thinking Small

One of the problems with relying on a single large colony is that horrible natural disasters can wipe out most or all of the colony in one shot. A meteorite strike on your colony, without any appreciable atmosphere to reduce the size of the meteorite, could potentially destroy everything you have. However, if you have started several smaller colonies and spread them out on the map, a meteorite strike of this magnitude may affect only one or two of your colonies, leaving the others unharmed. Although these natural disasters are rare events, planning for the worst is always a good idea when the survival of the human race is at stake.

A single mine can provide only a limited amount of resources per turn, and it will "play out" eventually, leaving you with an empty hole in the ground that has no value. By siting several colonies near different mines, your local resource supplies will last longer and be spread around with more efficiency.

Having several colonies necessitates longer transit connections for the transportation of traded items, resources, and population. When a new colony is struggling to survive, expensive power connections to a distant colony may be required. One advantage to having these connections is that, if a plague breaks out in one colony, its effects may be more isolated and less likely to be transmitted to another of your colonies. Now, manipulating the spread of the plague to your advantage by sending it to a rebel colony is a different matter, explained in more detail in this chapter under the heading of "The Typhoid Mary Gambit."

Thinking about It

Your grand strategy for colony development can be based on one large colony or several smaller colonies. Although each method has good and bad points, you'll find that the game itself is evenly balanced between the two, so your success will depend on maintaining your grand plan. For a long time, your colony's needs will be dependent on the stream of power and resources you're able to establish. Later, the birth and death rates among your colonists may be the limiting factor. In any case, this is a computer game, so you can always blow up your current planet and start over if you don't like the way things are developing.

Enhancing Your Artificial Intelligence

Computer science research into artificial intelligence allows you to generate multiple AI personalities for your colony. One of the limitations in the first phase of the game is that your initial AI adviser is a processor-intensive creation that can perform many functions simultaneously, taxing your colony's computer system. Research guides you toward smaller AI personalities who can be assigned specific tasks, such as managing the details of a specific colony under your general supervision. These smaller AIs, combined with the advanced computer processors you develop, can also aid scientific teams in their research, even though they're unable to do the kind of abstract and intuitive thinking required of human scientists.

New AI personalities are similar in many ways to humans. Among these similarities is the possibility that they will also have personality problems. These personality quirks in the early stages of multiple AI development can cause your AIs to behave in an unpredictable manner. When you have asked an AI to manage a specific colony's food production by building more Agricultural Domes, and it chooses to build factories for chia figurine production instead, it will become apparent that your AI manager has a psychological dilemma. Research into AI personality problems is basically psychotherapy for AIs. Completion of this research will solve any problems you might have with the multiple AI personalities, turning them into reliable digital administrators.

Macromanagement, explained in Chapter 18, is another feature that becomes available when you have multiple AI managers. This allows you to concentrate on the overall administration of your planet so that you don't have to handle all the details on every turn. Because of the load of information coming in from multiple colonies, you will probably find this to be a useful tool when your colonies grow large and unwieldy. You can, of course, still poke your fingers into everything on a micromanagement level if you prefer.

Direct Manipulation of Morale

Because morale is such an important factor in terms of human colonist performance in this game, the need to keep morale at a high level should be reemphasized. If morale drops low enough and stays there, you'll find that your colonists are sneaking off and defecting to the rebel colony. If morale stays high, your workforce will increase due to former rebels defecting to your colony.

Aside from using the media to manipulate public opinion, as described earlier in this chapter, you can also have a direct effect on morale by manufacturing luxury items for distribution through your Commercial structures. Luxury production and distribution was discussed in Chapter 10. This is the most effective continuous method of morale improvement.

Other methods of morale manipulation include the construction of Red Light Districts and the production of humanoid worker robots to free humans employed in factories for scientific and administrative jobs. Research into social and cultural subjects, listed in Chapter 17, can also improve morale. Maintaining a high Educational level among the population through the construction of Universities has short-term and long-term benefits for morale.

I Didn't Do It, Nobody Saw Me Do It, You Can't Prove Anything: How to Cheat

Once I've learned how to play a strategy game, the next thing I want to know is how to blow it up. This isn't motivated by any pent-up hostility on my part; I just want to see how the game will respond when I try to play it the "wrong" way. I think maybe if I'm clever enough, I'll find ways to trick the game and demonstrate the superiority of man over machine. This can be quite embarrassing when the machine wins, but it's not the sort of thing we usually tell our friends. To get you started in the right direction, I've mentioned a couple of unusual strategies here that I haven't already covered elsewhere in this book.

The Typhoid Mary Gambit

Spreading plague among your enemies is a tradition as old as human history. It was usually spread by accident until some clever person decided to make use of an otherwise bad situation. Mariners returning to Europe in 1346 spoke of a deadly epidemic that left thousands of corpses piled up in cities throughout China and India. The next year, trading ships sailed into European ports with crews dead or dying of the plague. Tradesmen continued spreading the plague all over Europe, which came to be known as the "Black Death." By 1348, millions were dying in England, France, Germany, and Austria. There wasn't enough room to bury them all, so corpses were burned or thrown into rivers.

Clever Tartar armies in Crimea used the plague to their advantage in battle. They catapulted corpses of plague victims over the walls of cities they had under siege. When the Scots invaded England, their troops became infected and brought the disease back to Scotland, where it spread with great speed. As a terrifying side effect, tens of thousands of estates needed to be settled, causing a tremendous boom in the need for lawyers. When the plague finally died out in 1351, an estimated 25 million people had expired in Europe, and we can guess that an equal number of lawyers appeared to pick over the remains.

You, too, can be a part of this noble tradition. If you're lucky enough to have the alien plague appear in one of your colonies, you have about 20 turns to make use of the disease before it destroys the entire population of that colony. If you have a monorail connection with the rebel colony, the plague will automatically be transmitted to their people as well. If you don't have a monorail connection, this would be an excellent time to run a monorail spur line off one of your main lines to connect your plague colony with the rebels.

It would also be a good idea to bulldoze one of the monorail tiles if you have a connection between your plague colony and another one of your own colonies that is unaffected. This should keep the plague from spreading. Once the plague has hopped a ride on a monorail, there's no stopping it unless you give everyone the alien virus cure.

While you're building that monorail line, you can perform medical research into the alien virus cure if you haven't discovered it already. That way, you have medicine you can start feeding to your population to control the damage in that colony. The distribution of this medicine is automatic if you have it stored in a warehouse. If you have no medicine, but a medical facility exists in the affected colony, it will slow the spread of the plague in that colony, giving you 40 turns before the entire population succumbs to the disease.

If the morale was very low among your colony's population when the plague arrived, there is a chance that the plague will spread to the rebel colony if any of your people decide to defect. The mechanism for defection is described elsewhere in this chapter.

The Criminal Empire Strategy

The Red Light District represents crime in your colony. You can build one of these areas to improve morale, use luxury items, and increase the birth rate, but there will also be a rise in the Crime level. The Red Light District can also appear on its own if morale drops low enough among your population. In this case, residential areas will be converted, one by one, into Red Light Districts. This also reduces the available residential living space, so you must build more Residential units to accommodate the displaced population, or else morale will drop even more due to crowded living conditions.

Lawbots and Police Stations can be used to limit the spread of Red Light Districts, but lawbots stop crime for only 10 turns and you can build only one Police Station in that amount of time. As hard to kill as a cockroach, the Red Light District will tend to move off somewhere else instead of just disappearing. So, what can you do?

Relax. Don't wear yourself out chasing the bad guys around. Let the Red Light District operate normally while you overlook it to manage other aspects of your colony. Don't build any Police Stations. Build more Red Light Districts and watch the morale of your population increase along with the birth rate. Don't worry about the Crime level. Make sure luxury production is sufficient to support a string of Red Light Districts, because each one automatically draws 2 units of luxury every turn. As long as you can manage the growth of your criminal empire, as well as the Crime level and the bad press, morale will climb astronomically.

The Robots for Humans Tactic

When you have developed the capability to build humanoid worker robots, your human workers can gradually be replaced so that they can join the scientists doing research. Scientific progress will advance faster if you have more laboratories operating and more scientists to staff them, so this is always a good tactic. Because your colonists perform manual labor only out of necessity, morale also climbs whenever you replace a human worker with a robot worker.

Tips from Machiavelli

Niccolo Machiavelli made some mistakes, but he was a clever fellow. His book on statecraft, *The Prince*, was an uncompromising discussion of the real activities that occur behind the public face of government. He was not concerned with lofty ideals, but with government that would last. Drawing on his own experience of office under the Florentine Republic, Machiavelli believed that a ruthless, efficient, defiant monarch was necessary to hold a strong government together. One of his basic principles was that, in politics, whether an action is evil or not can be decided only in the light of what it is meant to achieve and whether it successfully achieves it. With that in mind, here are a few tips from Machiavelli.

Men must be either pampered or crushed, because they can get revenge for small injuries but not for fatal ones. So any injury a prince does a man should be of such a kind that there is no fear of revenge.

Whoever is responsible for another's becoming powerful ruins himself, because this power is brought into being either by ingenuity or by force, and both of these are suspect to the one who has become powerful.

A wise ruler must devise ways by which his citizens are always and in all circumstances dependent on him and on his authority; and then they will always be faithful to him.

> *A man who wants to act virtuously in every way necessarily comes to grief among so many who are not virtuous. Therefore, if a prince wants to maintain his rule he must learn how not to be virtuous, and to make use of this or not according to need.*
>
> *Because it is difficult to combine them, it is better to be feared than loved if you cannot be both. Men worry less about doing an injury to one who makes himself loved than to one who makes himself feared.*
>
> *A prudent ruler cannot, and should not, honor his word when it places him at a disadvantage and when the reasons for which he made his promise no longer exist.*

Colony administrators who plan to be successful should keep these suggestions in mind, particularly when dealing with rebel colonists.

Ending It All

The point at which you end an *Outpost* game is your choice. Because the planet and its colonies are under your command, you are the logical one to decide when the game ends. For those who want to work toward a specific goal, you can gradually build up your space program until you've reached the point at which you can build a new colonization starship. When you decide to launch the mission, you'll see a reward sequence of images, followed by the end of the game and the virtual continuation of your empire.

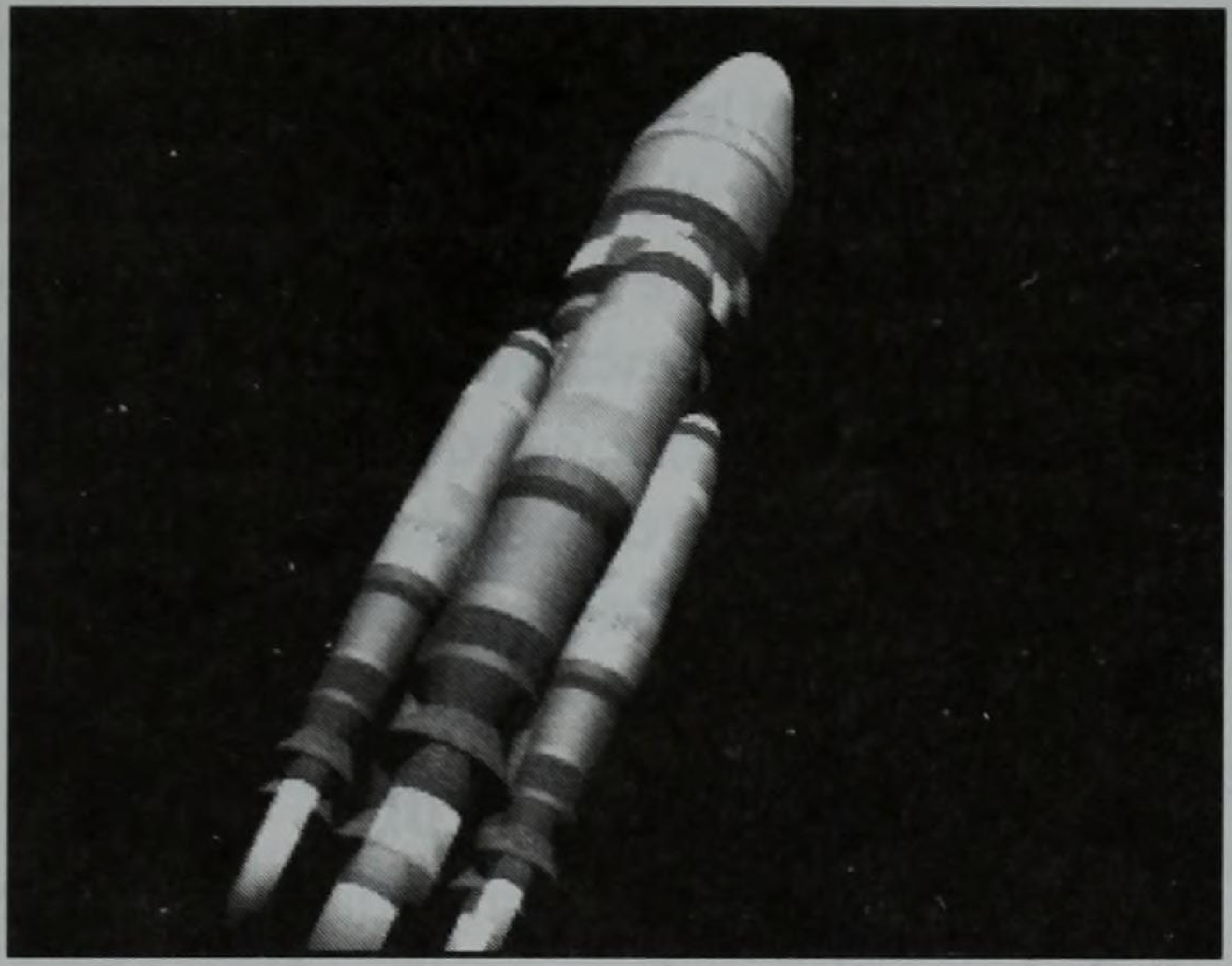
If you don't launch the new colonization mission, you can continue to play all the other aspects of the game until you die of old age or your computer explodes. Terraforming and nanotechnology also provide worthwhile subgoals, along with keeping your colonists so happy that the rebel colonists defect over to your side, adding themselves to your population. These subgoals are discussed in Chapter 17.

Space Program Buildup

If you're the sort of person who needs a traditional goal to feel as if you've reached a logical conclusion to the game, then the space program is for you. Although you may not have a gas giant planet in your new star system, you can mine the resources you need to fuel a variation of the same interstellar propulsion system that brought you to your new planet at the beginning of the game. The following research, discussed in Chapter 14, is necessary to make all the elements of the space program available:

Figure 20-3

Heavy lifter in flight

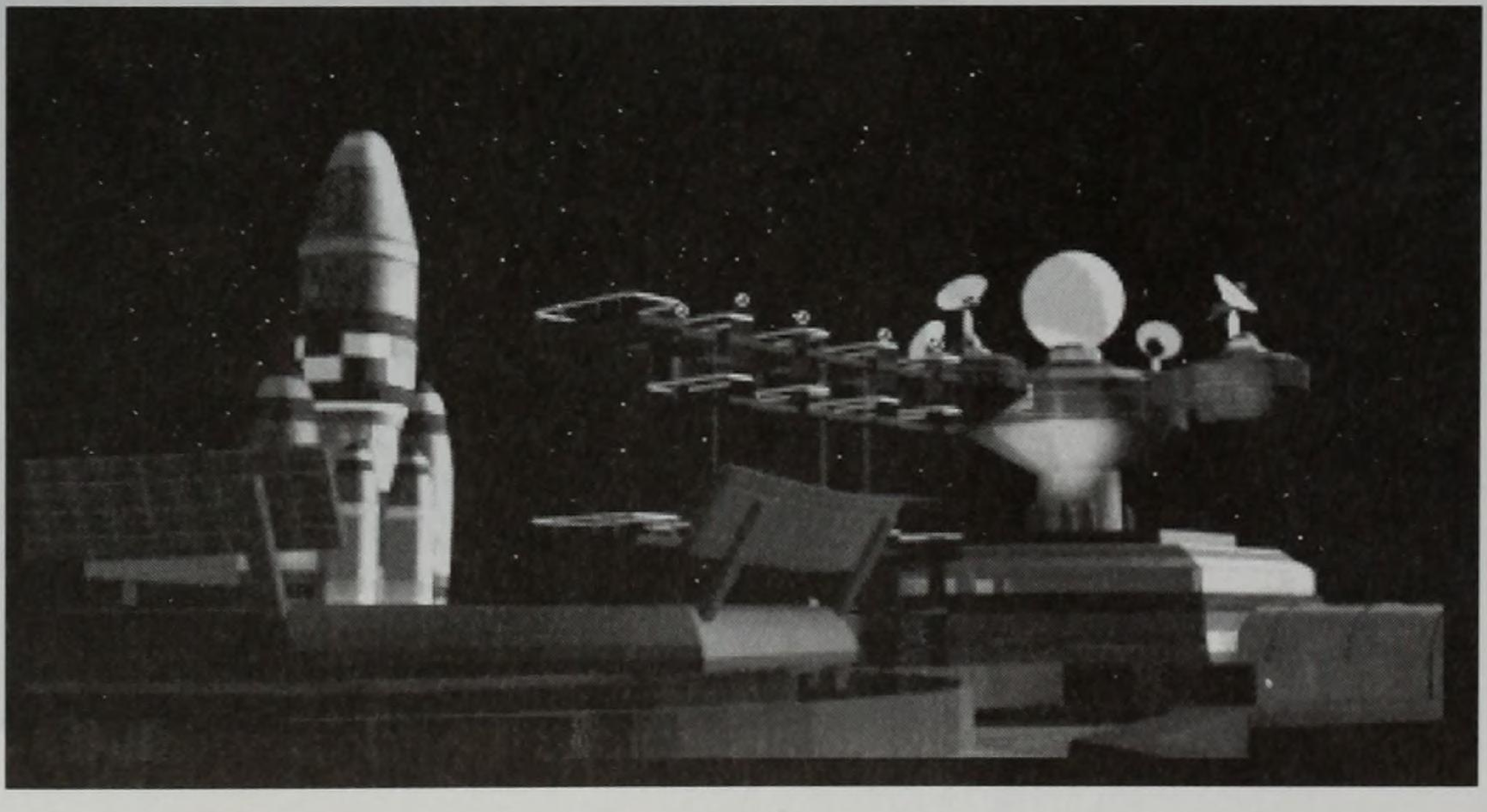


- Astrophysics
- Extraterrestrial Mining
- Celestial Mechanics
- Standard Propulsion Spacecraft
- Mathematics
- Wind Tunnels
- Spacecraft Testing and Analysis

When research in these areas has been completed, you still need to build the necessary technological elements that you've discovered, such as the Mass Driver and the heavy lifter spacecraft, shown in Figure 20-3. Large spacefaring items, such as the low-orbit freighter and the heavy lifter, are built and assembled at the Spaceport, shown in Figure 20-4, then stored in its Warehouse until you're ready to use them.

Figure 20-4

Your colony Spaceport



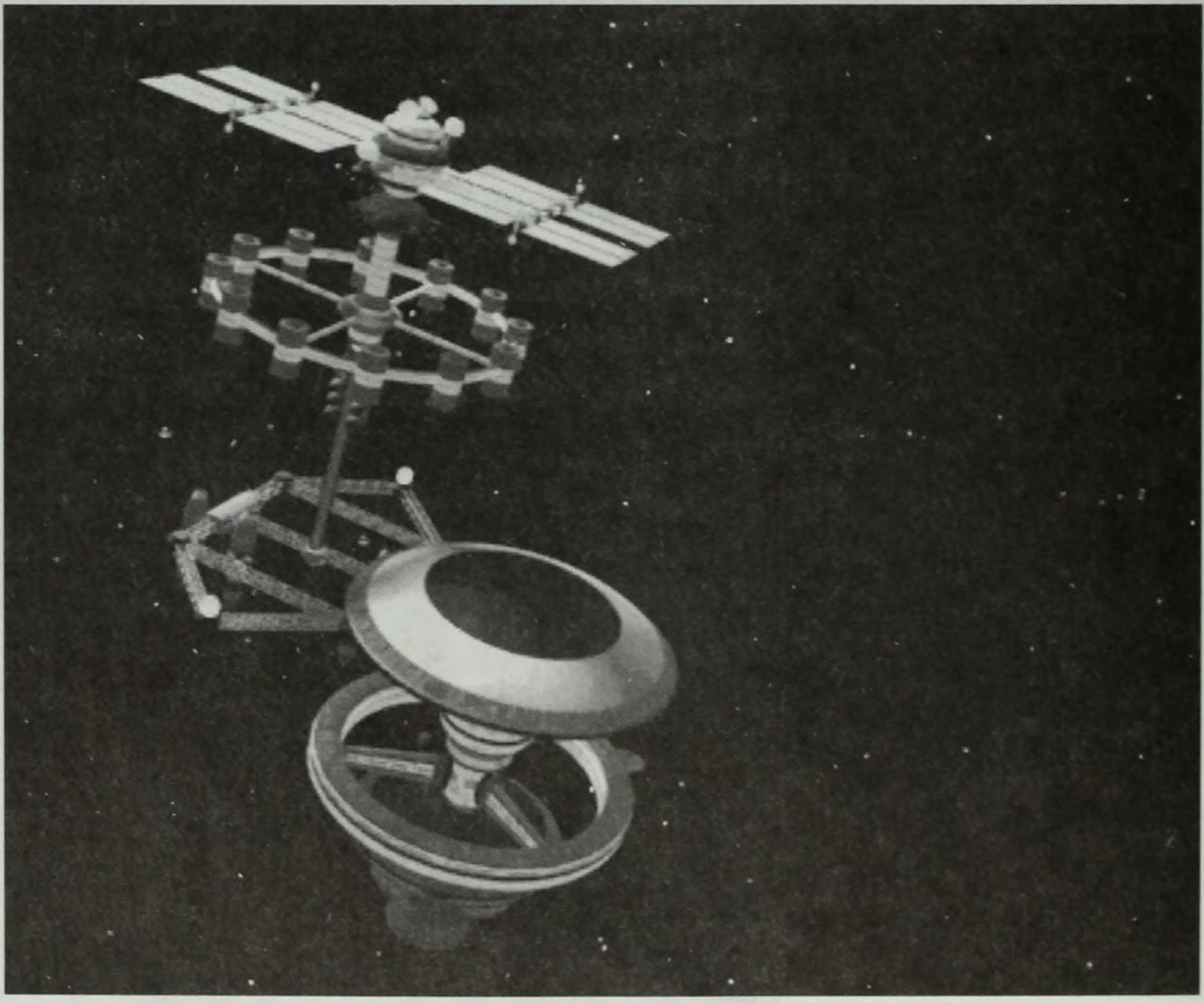
After your master AI has advised you that the colonization mission is ready to leave, you have the choice of launching at that time and ending the game, or holding the launch until you've played the rest of the game for a few hundred more hours. Launching the starship, shown ready to leave in Figure 20-5, will be your last official act as commander of the outpost colony. Although you can't actually reach those other worlds in this game, you will have managed to prove that human civilization will survive among the stars.

The Never-Ending Story

An *Outpost* game is a dynamic model. When you play the game all the way through more than once, you will find that you can never exactly duplicate a previous game session. Planets are different, environmental conditions are different, the colonists have a different collective personality, the AIs have more personality problems, different disasters occur at different frequencies, the equipment you packed on the starship is different, more robots are lost, fewer robots are built, humanoid workers replace more of the human population, your powersats are too far from the local

Figure 20-5

The second starship ready for launch



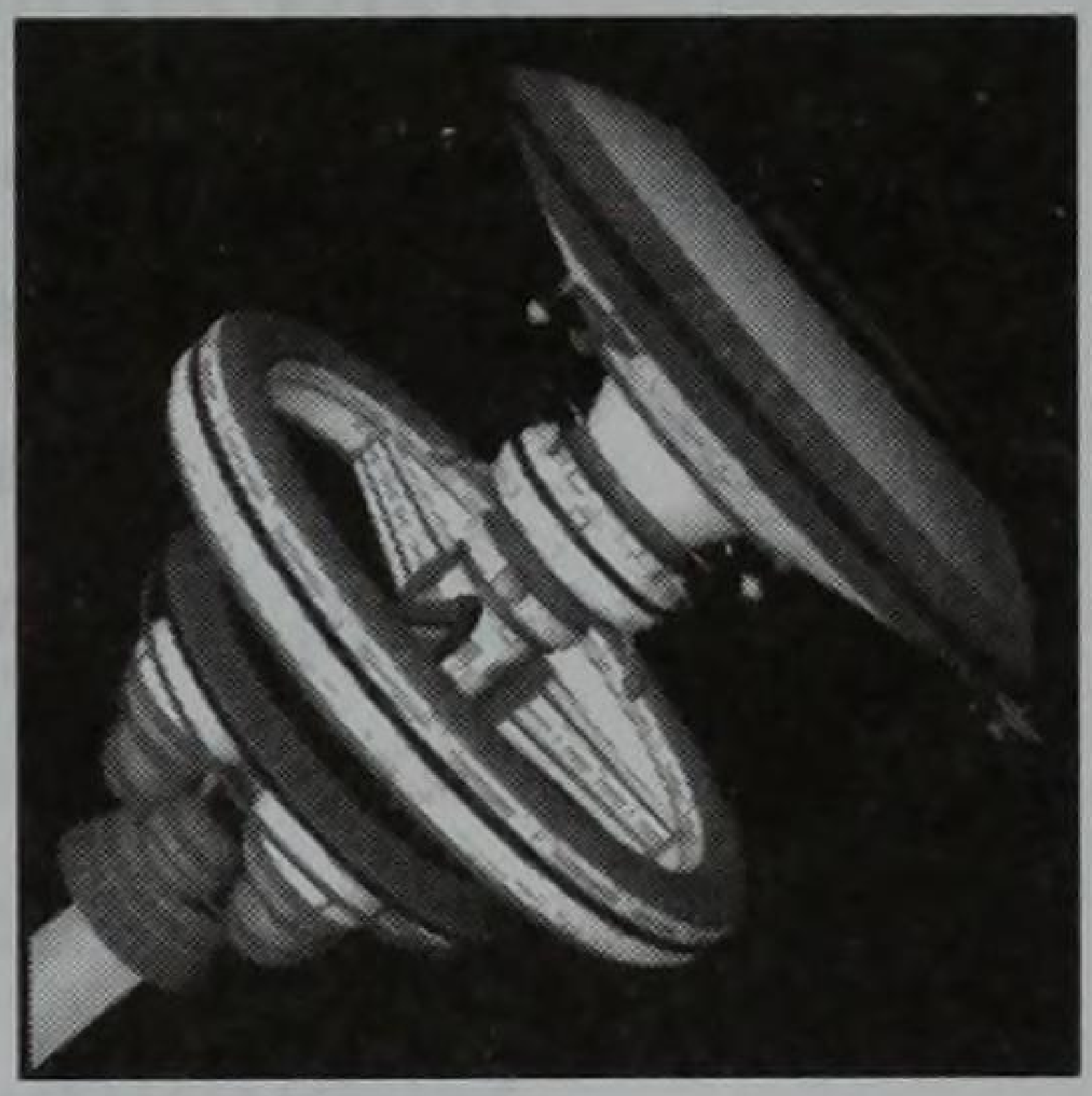
star to provide energy, geothermal power sources become available that you haven't seen before, the list just goes on and on. There are too many variables to duplicate the exact conditions of a previous *Outpost* game, resulting in greater playability and more game for your hard-earned money. Purchasing a computer game these days requires about the same amount of money as buying a small country, so we want you to feel that you've gotten full value out of the game after you took out a loan to buy it.

In this chapter, you've learned many of the secrets of the universe, including how to manipulate the media as a true politician would, how to spread disease to your enemies, how to think like a criminal genius, how to handle AI personality problems, how to cheat, how to control the end of the game, and a variety of tips for building a better colony.

The next chapter reveals the secrets of the stars, explaining all the lurid and shocking details of what you'll find in each star system. Armed with this information, you'll make no mistakes when you choose a new home among the stars for humanity.

Figure 21-1 The second colonization mission ends the game.

21



Secrets of the Stars

A day will come when beings shall stand upon
this Earth, as one stands upon a footstool,
and laugh and reach out their hands amidst
the stars.

H.G. Wells

The idea of navigating between the stars seems like an awesome prospect, but it might seem a little less daunting if you think of it in terms of your daily life. Let's say you're on a cross-country trip (interstellar voyage) in your car (starship), which is something exotic like a Lotus or a Ferrari. A friend of yours lives in a small town near Yosemite National Park in California (your target star system). Let's give this fictional town a name, perhaps something like Oakhurst (your target planet).

You've never been to Oakhurst before, but your clever friend (an astronomer) sent you a map before you left on your trip. At this point, you've left the interstate freeway and are traveling north on a highway that winds its way up into the mountains. Your map says Oakhurst is in those mountains, even though you can't see it yet (interstellar navigation). Trusting your map, you arrive in Oakhurst, braking (aerobraking) for the stoplight (the local star). A red light glows on your dashboard (virtual reality environment), warning you that your exotic engine (propulsion system) is overheating (starship decay). You also see the red lights of a highway patrol car in your mirror and realize that you just drove through a 35 mile per hour zone at 65 (speed trap). You're arrested (you land on the planet) and your car is impounded (remains in orbit). No one has ever heard of your friend (he works for Sierra On-Line).

See? It's not so hard to understand. You just have to get a grip on the terminology.

In *Outpost*, you have several options for gathering information on star systems. You can decide on your travel destination by guessing, by gathering information with your probes, or by letting your artificially intelligent starship pilot pick a star system.

Maps to the Stars' Homes

Let's say you just want to skip the whole interstellar probe and data-gathering process, but you don't want the artificial intelligence on the starship to run your life by picking your destination. The following star listings show all the pertinent details, including the number and type of planets in each star system. Bear in mind that this might be more information than you want, so avert your eyes if you fear too much game knowledge.

You'll notice that each star system is rated according to its likelihood of containing terrestrial planets. Shipboard trip time is also given in each listing. If you'd like more information on the types of stars and planets that are best suited to colonization, read the next chapter, which covers habitable planets.

Star: **TAU CETI**
Spectral class: G8
Apparent visual magnitude: 3.65
Mass: 0.82 times that of the Sun
Distance from Solar System: 11.7 light years
Trip time with our ship: 60.91 years (proper time aboard ship)
Probability of "habitable" planets within Tau Ceti's ecosphere: 0.036 (1 chance in 28)
Our planets: 3

- MARS CLASS
  - Hostility factor: 1
  - Total possible sites: 25
  - Actual sites generated: 10–14
- VENUS CLASS
  - Hostility factor: 7
  - Total possible sites: 3
  - Actual sites generated: 2–3
- MERCURY CLASS
  - Hostility factor: 9
  - Total possible sites: 2
  - Actual sites generated: 1

Tau Ceti is an isolated, main sequence star, meaning that it is smaller, cooler, fainter, less massive, and denser than the Sun. It has no companion stars. Yellow-orange stars of this class are not as plentiful as red dwarfs such as Barnard's Star, but have larger and more hospitable ecospheres that could support terrestrial-type planets.

Star: **ALPHA CENTAURI B** (trinary system)
Spectral class: K1
Apparent visual magnitude: 1.4
Mass: 0.88 times that of the Sun
Distance from Solar System: 4.2 light years
Trip time with our ship: 24.17 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0.057 (approximately 1 chance in 18)
Our planets: 2

- MARS CLASS
  - Hostility factor: 1
  - Total possible sites: 25
  - Actual sites generated: 10–14

PHOBOS CLASS
Hostility factor: 3
Total possible sites: 5
Actual sites generated: 3–5

The Alpha Centauri system consists of three stars.

Alpha Centauri A is a main sequence star very similar to our Sun, whereas Alpha Centauri B is somewhat smaller, of spectral class K1.

Star: **ALPHA CENTAURI A** (trinary system)
Spectral class: G4
Apparent visual magnitude: 0.09
Mass: 1.08 times that of the Sun
Distance from Solar System: 4.2 light years
Trip time with our ship: 24.17 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0.054 (approximately 1 chance in 19)
Our planets: 2
MARS CLASS
Hostility factor: 1
Total possible sites: 25
Actual sites generated: 10–14
MERCURY CLASS
Hostility factor: 9
Total possible sites: 2
Actual sites generated: 1

The Alpha Centauri system consists of three stars.

Alpha Centauri A is a main sequence star very similar to our Sun, with a spectral class of G4. Its apparent visual magnitude is 0.09, which makes it very bright. Its mass is about 1.08 times that of the Sun.

Alpha Centauri C (also known as Proxima Centauri) is far distant from the other two and can have no possible effect on the planets circling the larger components of the system. It is also far too small to have even the faintest chance of possessing a habitable planet.

Star: **EPSILON ERIDANI**
Spectral class: K2
Apparent visual magnitude: 4.2
Mass: 0.80 times that of the Sun

Distance from Solar System: 10.8 light years
Trip time with our ship: 56.5 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0.033 (1 chance in 30)
Our planets: 2
- VENUS CLASS
  - Hostility factor: 7
  - Total possible sites: 3
  - Actual sites generated: 2–3
- CERES CLASS ASTEROID
  - Hostility factor: 4
  - Total possible sites: 4
  - Actual sites generated: 2–3

Star: **70 OPHIUCHI A** (binary system)
Spectral class: F9
Apparent visual magnitude: 4.19
Mass: 0.90 times that of the Sun
Distance from Solar System: 17.3 light years
Trip time with our ship: 88.35 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0.057 (approximately 1 chance in 18)
Our planets: 2
- MARS CLASS
  - Hostility factor: 1
  - Total possible sites: 25
  - Actual sites generated: 10–14
- NEPTUNE CLASS GAS GIANT
  - Hostility factor: 11
  - Total possible sites: 0
  - Actual sites generated: 0

Star: **ETA CASSIOPEIAE A** (binary system)
Spectral class: F9
Apparent visual magnitude: 3.54
Mass: 0.94 times that of the Sun
Distance from Solar System: 18.0 light years
Trip time with our ship: 91.78 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0.057 (approximately 1 chance in 18)

Our planets: 2
  MARS CLASS
    Hostility factor: 1
    Total possible sites: 25
    Actual sites generated: 10–14
  MERCURY CLASS
    Hostility factor: 9
    Total possible sites: 2
    Actual sites generated: 1

Star: **SIGMA DRACONIS**
Spectral class: G9
Apparent visual magnitude: 4.72
Mass: 0.82 times that of the Sun
Distance from Solar System: 18.2 light years
Trip time with our ship: 92.76 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0.036 (1 chance in 28)
Our planets: 4
  MARS CLASS
    Hostility factor: 1
    Total possible sites: 25
    Actual sites generated: 10–14
  MOON (orbiting MARS CLASS)
    Hostility factor: 2
    Total possible sites: 20
    Actual sites generated: 8–13
  MERCURY CLASS
    Hostility factor: 9
    Total possible sites: 2
    Actual sites generated: 1
  VENUS CLASS
    Hostility factor: 7
    Total possible sites: 3
    Actual sites generated: 2–3

Star: **36 OPHIUCHI A** (trinary system)
Spectral class: K2
Apparent visual magnitude: 5.17
Mass: 0.77 times that of the Sun
Distance from Solar System: 18.2 light years
Trip time with our ship: 92.76 years (proper time aboard ship)

Probability of "habitable" planets within this star's ecosphere: 0.023 (1 chance in 43)
Our planets: 1
PLUTO CLASS
Hostility factor: 8
Total possible sites: 10
Actual sites generated: 5–8

Star: **36 OPHIUCHI B** (trinary system)
Spectral class: K1
Apparent visual magnitude: 4.9
Mass: 0.76 times that of the Sun
Distance from Solar System: 18.2 light years
Trip time with our ship: 92.76 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0.020 (1 chance in 50)
Our planets: 1
PHOBOS CLASS
Hostility factor: 3
Total possible sites: 5
Actual sites generated: 3–5

Star: **HR 7703 A** (binary system)
Spectral class: K2
Apparent visual magnitude: 5.24
Mass: 0.76 times that of the Sun
Distance from Solar System: 18.6 light years
Trip time with our ship: 94.72 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0.020 (1 chance in 50)
Our planets: 1
NEPTUNE CLASS GAS GIANT
Hostility factor: 11
Total possible sites: 0
Actual sites generated: 0

Star: **DELTA PAVONIS**
Spectral class: G7
Apparent visual magnitude: 3.67
Mass: 0.98 times that of the Sun
Distance from Solar System: 19.2 light years
Trip time with our ship: 97.66 years (proper time aboard ship)

Probability of "habitable" planets within this star's ecosphere: 0.057 (approximately 1 chance in 18)
Our planets: 4
 MARS CLASS
  Hostility factor: 1
  Total possible sites: 25
  Actual sites generated: 10–14
 MOON (orbiting MARS CLASS)
  Hostility factor: 2
  Total possible sites: 20
  Actual sites generated: 8–13
 MERCURY CLASS
  Hostility factor: 9
  Total possible sites: 2
  Actual sites generated: 1
 SATURN CLASS GAS GIANT
  Hostility factor: 10
  Total possible sites: 0
  Actual sites generated: 0

Star: **82 ERIDANI**
Spectral class: G5
Apparent visual magnitude: 4.3
Mass: 0.91 times that of the Sun
Distance from Solar System: 20.9 light years
Trip time with our ship: 105.99 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0.057 (approximately 1 chance in 18)
Our planets: 2
 MARS CLASS
  Hostility factor: 1
  Total possible sites: 25
  Actual sites generated: 10–14
 PLUTO CLASS
  Hostility factor: 8
  Total possible sites: 10
  Actual sites generated: 5–8

Star: **BETA HYDRI**
Spectral class: G1
Apparent visual magnitude: 2.90

Mass: 1.23 times that of the Sun
Distance from Solar System: 21.3 light years
Trip time with our ship: 107.95 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0.037 (approximately 1 chance in 28)
Our planets: 2
  MARS CLASS
    Hostility factor: 1
    Total possible sites: 25
    Actual sites generated: 10–14
  MOON
    Hostility factor: 2
    Total possible sites: 20
    Actual sites generated: 8–13

Star: **HR 8832**
Spectral class: K3
Apparent visual magnitude: 5.67
Mass: 0.74 times that of the Sun
Distance from Solar System: 21.4 light years
Trip time with our ship: 108.44 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0.011 (1 chance in 90)
Our planets: 2
  MERCURY CLASS
    Hostility factor: 9
    Total possible sites: 2
    Actual sites generated: 1
  JUPITER CLASS GAS GIANT
    Hostility factor: 11
    Total possible sites: 0
    Actual sites generated: 0

Star: **BARNARD'S STAR**
Spectral class: M4
Apparent visual magnitude: 9.54
Mass: 0.15 times that of the Sun
Distance from Solar System: 6.0 light years
Trip time with our ship: 32.5 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0

Our planets: 1
JUPITER CLASS GAS GIANT
Hostility factor: 11
Total possible sites: 0
Actual sites generated: 0

With this class of star, there is no chance of a "habitable" planet within the star's ecosphere.

Star: **WOLF 359**
Spectral class: M6
Apparent visual magnitude: 13.7
Mass: 0.1 times that of the Sun
Distance from Solar System: 7.5 light years
Trip time with our ship: 40.33 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0
Our planets: 1
JUPITER CLASS GAS GIANT
Hostility factor: 11
Total possible sites: 0
Actual sites generated: 0

With this class of star, there is no chance of a "habitable" planet within the star's ecosphere.

Star: **SIRIUS**
Spectral class: A1
Apparent visual magnitude: -1.47
Mass: 2.3 times that of the Sun
Distance from Solar System: 8.6 light years
Trip time with our ship: 45 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0
Our planets: 1
JUPITER CLASS GAS GIANT
Hostility factor: 11
Total possible sites: 0
Actual sites generated: 0

With this class of star, there is no chance of a "habitable" planet within the star's ecosphere.

Star: **ROSS 248**
Spectral class: M6
Apparent visual magnitude: 12.24

Mass: 0.13 times that of the Sun
Distance from Solar System: 10.1 light years
Trip time with our ship: 53.07 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0
Our planets: 1
JUPITER CLASS GAS GIANT
Hostility factor: 11
Total possible sites: 0
Actual sites generated: 0

With this class of star, there is no chance of a "habitable" planet within the star's ecosphere.

Star: **PROCYON**
Spectral class: F5
Apparent visual magnitude: 0.38
Mass: 1.8 times that of the Sun
Distance from Solar System: 11.4 light years
Trip time with our ship: 59.44 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0
Our planets: 1
JUPITER CLASS GAS GIANT
Hostility factor: 11
Total possible sites: 0
Actual sites generated: 0

With this class of star, there is no chance of a "habitable" planet within the star's ecosphere.

Star: **KRUGER 60**
Spectral class: M3
Apparent visual magnitude: 9.77
Mass: 0.25 times that of the Sun
Distance from Solar System: 13 light years
Trip time with our ship: 67.28 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0
Our planets: 1
JUPITER CLASS GAS GIANT
Hostility factor: 11
Total possible sites: 0
Actual sites generated: 0

With this class of star, there is no chance of a "habitable" planet within the star's ecosphere.

Star: **ALPHA AQUILAE** (ALTAIR)
Spectral class: A7
Apparent visual magnitude: 0.8
Mass: 2 times that of the Sun
Distance from Solar System: 16 light years
Trip time with our ship: 81.98 years (proper time aboard ship)
Probability of "habitable" planets within this star's ecosphere: 0
Our planets: 1
  JUPITER CLASS GAS GIANT
    Hostility factor: 11
    Total possible sites: 0
    Actual sites generated: 0

With this class of star, there is no chance of a "habitable" planet within the star's ecosphere.

Stargazing

I'm sure you noticed that some of the star systems have no habitable planets. This demonstrates the value of research; if you let Fate determine your destination, you and your colonists might find yourselves orbiting a gas giant planet that you can't land on.

This chapter has shown you the possible destinations you can select at the beginning of the game. If you prefer the more realistic aspect of not being sure what kind of planet you're going to until your probe data confirms it, then you shouldn't have read this far in this chapter.

The next chapter will discuss what constitutes a "habitable" planet, which your colonists can live on without exploding or sinking down through the surface to the core of the planet. As these habitable planets are defined, they're the easier places to colonize, but tougher environments are available if you don't wish to take the easy way out. After all, forcing your colonists to live on a horrible planet builds character, right? If they complain, just tell them to evolve if they don't like it.

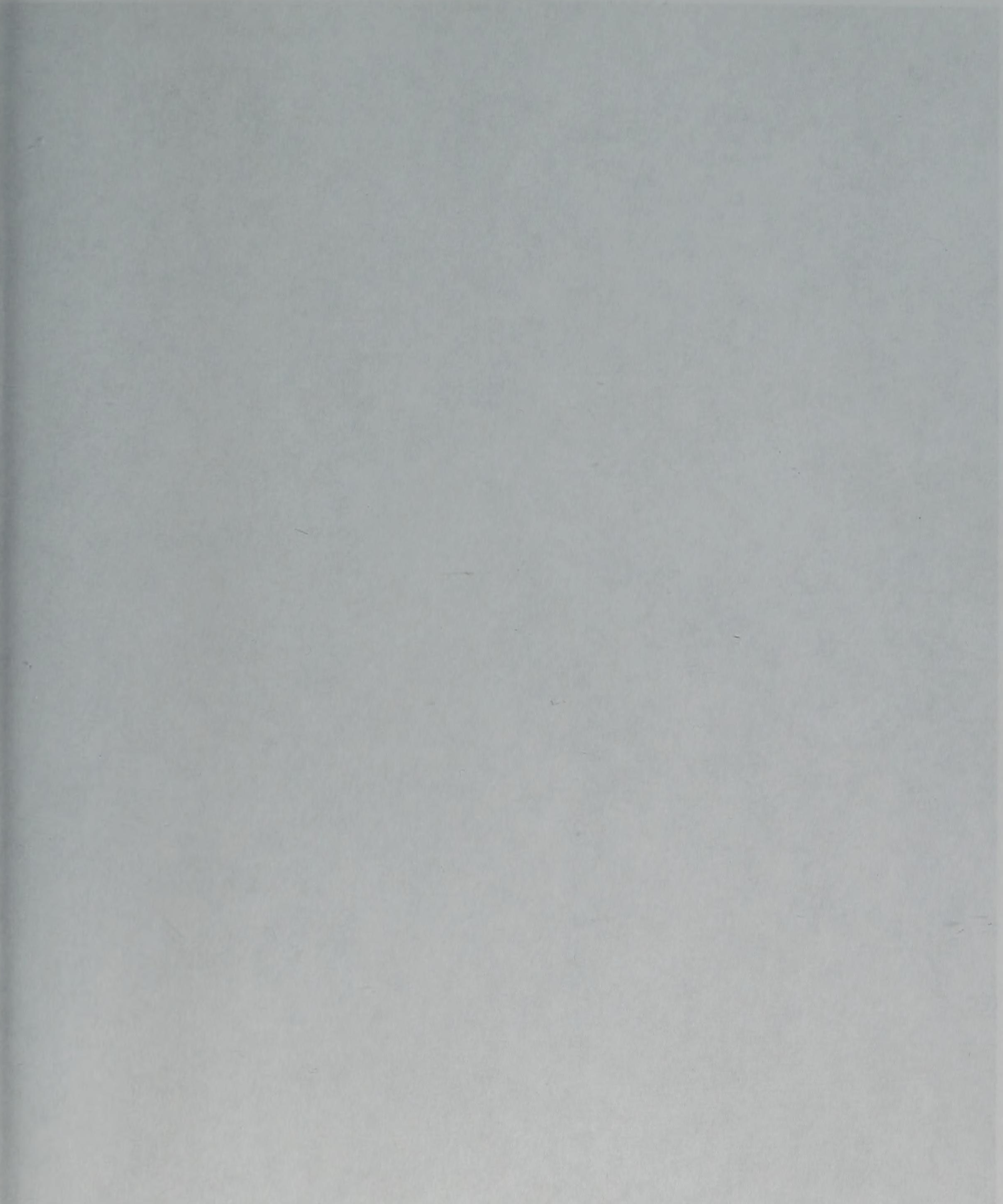


Figure 22-1 Earth before the "Hammer"

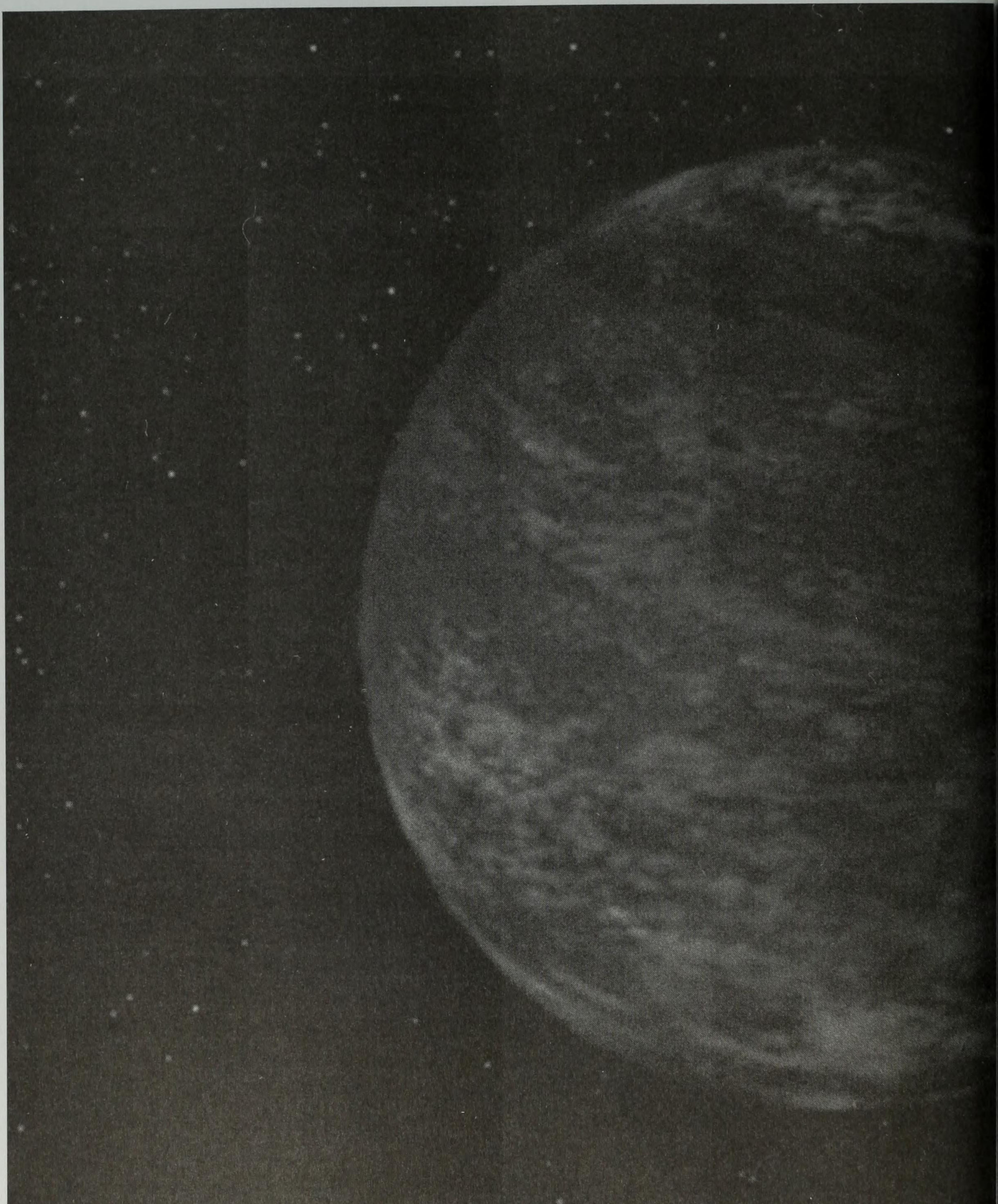


Figure 22-1 Earth before the "Hammer"

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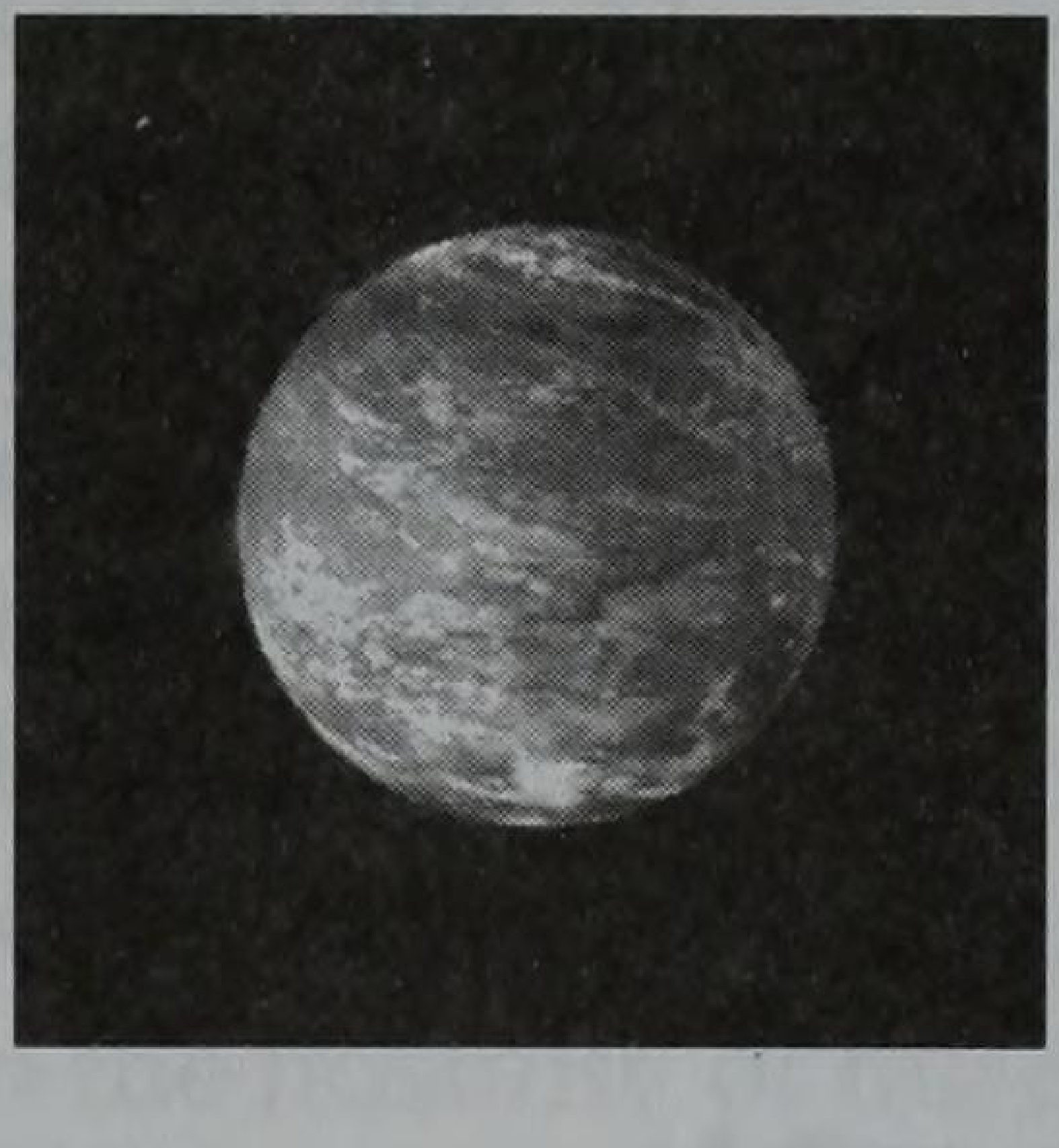


Habitable Planets: Should You Buy or Rent?

To consider the Earth as the only populated world in infinite space is as absurd as to assert that on a vast plain only one stalk of grain will grow.

Metrodoros of Chios, fourth century B.C.

Only one location in our solar system satisfies the requirements to support human life without artificial aid. Searching for other planets that have an environment similar to the Earth's is a difficult business, requiring educated guesses based on star types and a variety of imperfect planetary detection methods. For the near future, the tools at hand are not sophisticated enough to verify the existence of terrestrial planets orbiting distant stars. However, we can infer the existence of planets based on what we know of the Solar System and theories regarding the evolution of planetary bodies around different classes of stars. This chapter discusses the development of an Earth-type planet, the likelihood of planets orbiting typical stars, the detection of planets distant from Earth, the habitability and problems of different planetary types, and the possibility of life in other planetary systems.

A Horrible Place to Visit and You Have to Live There

About 400 million years ago, many of the early amphibians may have thought that the land was a nice place to visit, but they wouldn't want to live there. As in human society, it would be easy to speculate that there was disagreement on this topic. Whether they were seeking new food sources, avoiding predators, or simply trying to prove a point, a radical group among the amphibians decided to leave town and colonize the land. They were quite successful in that endeavor. Since that time, living on land has become quite popular.

NASA and the other space agencies of the world might be considered the modern ancestors of those radical amphibians. They are the new radicals trying to prove that we can live in space and on other planets. Our first faltering steps have taken us to the Moon; our robots have visited all the other planets except Pluto, which has been observed only from a distance. As our steps become more confident, we'll continue outward and reach for the stars. As the amphibians colonized land, we will colonize distant planets. With any luck, we will be just as successful. But where will we go? What should we look for? Will we be able to find a McDonald's when we get there?

To begin with, we'll assume that our Solar System is not an unusual planetary grouping. There is a wide variety of planetary types in our neighborhood, ranging from a gas giant planet with an interior of liquid metallic hydrogen, a physical state unknown on Earth, to a hot world with a thick "greenhouse" atmosphere topped with sulfuric acid. Strange as they may seem, our local planets can be treated as a typical sample of the bodies that probably exist around other stars. Rarest of all is the small water planet on which organic molecules have evolved to the point of developing computer games for their own amusement.

Habitability

In seeking the optimum conditions making terrestrial planets habitable, we can draw certain conclusions based on what we know of the Earth. Planets falling within a reasonable range of these conditions may not be as friendly to humans as an Earth-like world, but at least they should be less hostile. For our purposes, planets falling outside these optimum conditions may also be able to support human colonies, but heavier protective measures will be required for those humans to survive. When the computer on the colonization ship studies a planet on arrival, it will also select potential landing sites according to the hostility of the environment, so you will be presented with fewer options on a Venus-type planet than you would on a Mars-type planet. As a basis for comparison, let's take a look at the set of conditions required to generate a planet with an environment that's near optimum for human habitation.

To qualify as a mature and optimum planet to colonize, a world needs to have existed for 2 to 3 billion years under a steady amount of solar radiation. The Earth is about 5 billion years old. Evidence of life on the Earth extends back about 3 billion years, so it took about 2 billion years for conditions to stabilize to the point at which life could develop. With the spread of life increasing the amount of oxygen in the air, more complex organisms developed over the next billion years, making the Earth a more suitable place to live. In other words, a fresh new planet requires time to ripen before it becomes habitable.

A Planet Ripe for Picking

The aging process required to create an Earth-type planet with suitable living conditions might proceed as follows:

1. Through the gradual accretion and capture of small particles, including dust bunnies and bits of loose hair, the planet is formed.
2. Lacking further loose materials to build on, the surface of the planet is rough and airless. Tourism is at an all-time low.
3. As a result of gravitational compression, the interior of the planet is hot. Internal readjustments continue: denser materials, such as iron, flow downward while lighter materials, such

as rocky silicates and Styrofoam, flow upward. This is a slow process that also creates movement in the surface materials, causing earthquakes, volcanic activity, and crustal migration. Friction in the crust, and the decay of radioactive potassium and uranium in the mantle, create high temperatures that release trapped gases.

4. Although the heavier gases stay with the planet, the lighter gases, such as hydrogen, helium, and neon, make a break for it and escape their planetary prison. In the mad rush to leave, gases such as methane and ammonia may be left behind in the traffic jam. Much of the water vapor that is produced reacts to sunlight and is broken down by photolysis into hydrogen and oxygen. The hydrogen takes the first train out of town, and the oxygen enters into chemical reactions with surface materials.
5. Stable gases, such as nitrogen and carbon dioxide, also get caught in the traffic jam. With nothing else to do, they join with their methane and ammonia friends to form an atmosphere.
6. Forming an atmosphere continues catching on as the thing to do on the primitive world. With the ongoing process of volcanic action, the production of water vapor exceeds the rate of loss through photolysis. Free oxygen and ozone begin to accumulate through the photolysis of water.
7. Desperate for a shower, the ozone and oxygen decide to make friends with the water vapor by slowing down the photolysis process, allowing more water vapor to accumulate. The ozone also creates a stable upper level of the atmosphere known as the "cold trap," which results in the freezing and precipitation of water.
8. Water begins to accumulate on the planet's surface when the atmospheric pressure is high enough and the temperature remains above the freezing point of water. Because water loves a party, it starts collecting to form oceans.
9. As volcanic activity continues during ocean formation, the carbon dioxide goes into solution, forming carbonic acid. This acid reacts to form carbonate rocks. Not wanting to be left behind, the ammonia also goes into solution. The remaining atmosphere consists of nitrogen and methane, small amounts of carbon dioxide, and water vapor.

10. Bigger oceans create more rainfall. Soluble minerals are washed into the seas.
11. With the energy from sunlight, more complicated chemical reactions occur in the oceans. Lightning forms nitrogen oxides; these dissolve into nitric acid and nitrates, which will be processed into hot dogs. Sulfur dioxide from volcanoes dissolves to form sulfuric acid and sulfates, which may also be processed into hot dogs.
12. Life rears its ugly head on the planet. Hot dogs are everywhere. Photosynthesis begins, causing oxygen to accumulate faster than it could through photolysis alone. Clever bacteria develop enzymes and organic dyes to obtain energy from the iron and sulfur compounds dissolved in the ocean. Blue-green algae make their appearance, making oxygen in the water. Ammonia and methane decline as the blue-green algae save the world by controlling the greenhouse effect.
13. The oxygen content of the atmosphere finally reaches the minimum level required by land vertebrates. Volcanic activity slows, the number of meteorites striking the ground diminishes, and the planet is ready for tourism. After 3 billion years of life on the planet, computer games form.

Many factors can interfere with this process, which is why we don't have a Solar System full of Earth-type planets. One of the major factors is the planet's distance from its primary star.

Stellar Ecospheres

The distance of a planet from its primary star determines how much radiation it will receive from that star. The habitability of a planet depends on the quantity of this *illuminance.*

The illuminance varies with the square of the distance of a planet from its primary. If one planet is twice as far from the primary as a second planet, the first planet receives four times less light. If it's 5 times as far, it receives 25 times less illuminance. This also explains why a solar panel doesn't produce as much power at the orbit of Pluto as it would at the orbit of Mercury.

A stellar *ecosphere* is a region of space near a star where planets can exist with surface conditions suitable to life. The ecosphere is bounded by two spherical shells centered on the primary. Within the inner shell, illuminance levels are too high for habitability; outside the outer shell they are too low. The ecosphere between the two shells provides just the right amount of light to keep everybody happy. Illuminance in the range from 0.65 to 1.9 times Earth normal would allow planets with reasonable surface temperatures to exist.

A bright, hot star will have a larger ecosphere than a dim, cool star. In our Solar System, the ecosphere extends from the orbit of Venus halfway to the orbit of Mars. To be more precise, our ecosphere extends from 67.5 million to 115 million miles from the Sun, with the illuminance ranging from 1.9 times that of Earth to 0.65 times that of Earth. However, when the Earth formed, the Sun's ecosphere was smaller. Because of the buildup of helium in the Sun's core, resulting from the fusion of its hydrogen, the Sun emits more energy now than it did 4.5 billion years ago. Estimates show that the Sun is about 40 percent brighter at present. With the Sun that much dimmer, the Earth as it is today would have been colder and the oceans would have frozen solid, reflecting most of the sunlight back into space and preventing the origin of life.

Earth escaped freezing by wearing a thermal blanket—the primordial atmosphere that trapped the Sun's heat to keep the oceans from freezing. For long periods, this "greenhouse effect" maintained an average temperature of at least 41 degrees Fahrenheit over the entire planet. The presence of ammonia and methane in the early atmosphere may have driven the average temperature up to 170 degrees Fahrenheit. At present, the remaining greenhouse effect warms the Earth's surface to about 60 degrees Fahrenheit.

It was a close call for Earth in the early days. Estimates show that Earth would have overheated from a runaway greenhouse effect if it had formed more than 5 percent closer to the Sun, but it would have frozen if it had formed in an orbit more than 2 percent farther away.

Although there are some 130 billion stars that formed between 4.5 and 11 billion years ago, making them a suitable age to support planets with life, we are also fortunate that Earth formed around the proper type of star. Of those 130 billion stars, perhaps only 13 billion of them can support planets. Many of them are the small and cool red dwarfs; these will burn for hundreds of billions of years, but provide little heat at a distance. The blue stars are hot and bright, but they burn out so fast that their planets will perish before life can evolve there.

With the restrictions discussed in this chapter, there are estimated to be 880,000 planets like Earth in the Galaxy. These planets would have a star similar to our Sun. They would also be of similar size and appearance to Earth, as well as being old enough to have experienced the Cambrian period over half a billion years ago. These planets also have the necessary conditions to support intelligent life.

Life in Other Neighborhoods

Searching for good stellar neighborhoods to live in? Consider what many scientists believe to be reasonable assumptions about star systems that can support life. This doesn't mean you're going to find intelligent life in *Outpost*, but this information can be used as an additional guideline for choosing a star system you'd like to colonize.

NASA's Ames Research Center (Mountain View, California) conducted a study regarding *Project Cyclops*, a proposal to build a large antenna array designed to search the sky for radio signals. This array would have been powerful enough to detect signals originating from civilizations up to 1,000 light years away. Listed here are some of the assumptions behind the proposal.

- Planetary systems are the rule, not the exception. Most stars are now believed to have these systems, a by-product of the mechanism for forming stars.
- Most planetary systems will have at least one planet in the stellar ecosphere where it will be kept warm by its star, but not too hot, and where its primitive atmosphere can evolve into an oxidizing Earth-like atmosphere.
- Organic precursors of life form in abundance from the ingredients in a primordial atmosphere, but they are also found in space and on some meteorites (the carbonaceous chondrites).
- Main sequence stars cooler than F5 stars have lifetimes long enough to make Darwin-Wallace evolution effective. The ecospheres of stars cooler than spectral class K7 are so close to the star that tidal friction will either synchronize or greatly diminish the planet's rotation.
- On a substantial fraction of F, G, and K classes of main sequence stars, intelligent life will have existed at some time during the life of the star on favorably situated planets.
- The longevity of technologically advanced civilizations is unknown within orders of magnitude. Other than assessing our

own chances for long-term survival, we know of no way to resolve this question, short of actually making contact with other races.

- Establishing interstellar contact may greatly prolong the life expectancy of the race that does so. Races that have solved their ecological and social problems and are therefore very long-lived may already be in mutual contact, sharing a vast pool of knowledge. Access to this "galactic heritage" may well prove to be the salvation of any race whose technological prowess is advanced enough to reach it.

Optimum Accommodations for Tourists

To satisfy the requirements for a planet that will sustain life, thereby gaining full approval from the Auto Club, a habitable world must pass these tests:

- *Rotation period:* The planet should have a period of rotation less than 96 hours to prevent high and low temperatures that are too extreme.
- *Illuminance:* The illuminance at low equatorial inclination should be between 0.65 and 1.35 times Earth normal to maintain temperatures consistent with good habitability.
- *Orbital eccentricity:* The orbital eccentricity should be less than 0.2, because greater values might also produce temperatures that are too extreme.
- *Mass:* Its mass should be greater than 0.4 times the mass of the Earth. This permits the planet to produce and retain a breathable atmosphere. Its mass should also be less than 2.35 times the mass of the Earth so that its surface gravity will be less than 1.5 *g*.
- *Age:* The age of the planet, as well as its primary star, should be greater than 3 billion years to allow for the appearance of complex life forms that can play computer games in a breathable atmosphere.
- *Mass of primary:* The mass of the primary should be less than 1.43 times the mass of our Sun. This ensures that the star has resided on the main sequence for over 3 billion years. For habitable planets in general, the mass of the primary should be greater than 0.72 times the mass of our Sun. When primaries have masses smaller than this, the illuminance and rate of rotation would be incompatible with good habitability. A special

case would be a planet with a large or close satellite, allowing a primary mass as low as 0.35 times that of our Sun.

- *Decent restaurant:* To gain full approval from the Auto Club, a planet should also possess a decent restaurant, which means good food and good service at a reasonable price.

Detecting Planetary Systems

It is generally accepted that many of the claimed discoveries of planets outside our Solar System are false. This does not rule out the possibility of planets around those stars, but the development of instruments with the capability of detecting the largest extrasolar planets, the gas giants and brown dwarfs, has been quite recent. An actual discovery will have to be confirmed by an independent party with different measuring techniques or instruments.

The first unseen object to be detected outside the Solar System was not a planet, but a new type of star. Astronomers had been puzzled for a long time over small variations in the motion of the star known as Sirius. In fact, they were quite serious about it. Instead of moving in a straight line, Sirius moved like a drunken sailor, wobbling from one side to the other of its predicted course. Astronomers prefer objects that move in straight lines, so something had to be done about the situation. The man who finally did something was F. W. Bessel, a man who was quick with a pencil. Bessel calculated that the silly motion of Sirius was due to an unseen companion of considerable mass. He was correct, but the companion star remained unobserved until 1864. Still later, studies demonstrated that the companion, Sirius B, is a bizarre object known as a *white dwarf* star. The mass of this little fellow is about 25 percent the mass of our Sun, but it has an incredible density resulting from the strong gravitational field at its core. This field squeezes the material at the core into a degenerate state to which normal laws relating density to gas pressure and temperature do not apply. The degenerate state also explains why so many white dwarfs get arrested.

It is believed that a white dwarf will cool over billions of years, its nuclear fire spent, radiating residual heat until its light goes out and it becomes a black dwarf, a mere shadow of its former self. Our own Sun will end its life in similar fashion, perhaps wandering around the galaxy accompanied by the remnants of the planets it reduced to cinders during its red giant phase.

The detection of planets outside our Solar System is a difficult process. Because a planet doesn't shine with any light of its own, it's forced to bask in the reflected glory of the nearby star it circles. This makes the planet almost impossible to see visually because it's dimmer than the star and its reflected light is lost in the star's glare. Stars feel as if they have all the responsibility for maintaining relationships, so stars are always glaring at planets.

At interstellar distances, the angular separation between a planet and star is tiny, from fractions of an *arc second* to several arc seconds at best. For comparison, an arc of 1 second is less than the apparent diameter of a U.S. dime when viewed from a distance of 2 miles. There is also the difficulty of viewing such a target with a large telescope through Earth's shifting atmosphere.

However, visual observation isn't the only way to find a planet. The methods of detecting other planetary systems can be lumped into two general categories: indirect and direct techniques. Indirect methods are used to infer the existence of an unseen companion to a star, by measuring effects that the companion has on the star. Direct methods involve the observation of electromagnetic radiation from the companion itself. This can be thermal radiation, visible light reflected from the companion's stellar neighbor, or some form of nonthermal radiation intrinsic to the companion.

Indirect planetary detection methods are becoming more sophisticated all the time. *Astrometry* involves detecting changes in a star's path caused by a nearby companion. Although existing astrometric accuracy is insufficient for a comprehensive search for other planetary systems, it's impressive to realize that existing accuracy is equivalent to measuring the width of a human hair as viewed from several miles away. Astrometry can, at least, determine whether massive planets are orbiting any of the closest stars. *Spectroscopy* is used to detect changes in a star's velocity due to nearby companions. *Photometry* is used to detect variations in a star's luminosity caused by the alignment of a companion between the star and Earth, thus eclipsing the star. *Speckle interferometry* is a mathematical image reconstruction technique that improves optical and infrared images by removing atmospheric interference. Scientists have at used speckle interferometry at infrared wavelengths to detect dim companion stars. Because of their mass, companion stars are easier to detect than planets, but the technique continues to be refined.

Newer plans involve the idea of *optical interferometry* based on the Moon or in space, allowing the direct imaging of extrasolar planets with a high level of detail. Although Jovian "gas giant" planets will be the easiest to locate, this method will also allow the discovery of terrestrial planets. This technique requires widely separated optical telescopes to make use of the interference pattern of light waves coming from closely spaced points in the sky. The greater their baseline, or separation, the better the resolution. This is similar to radiotelescope interferometry, which uses radio sources in the sky instead of light sources.

In *Outpost*, data for the selection of a star system to colonize can also be obtained through *very long baseline interferometry* (VLBI) and *ultra long baseline interferometry* (ULBI). These methods expand on the idea of interferometry by using widely separated space probes to gather data. Unlike ground-based interferometry, the data between probes will have to be synchronized, because otherwise they'll be moving in different directions at different speeds. The VLBI probes will gather data from within the Solar System, giving you basic information about the star systems you're interested in. The ULBI probes are interstellar, so they can form a long baseline between themselves and the starship for optical planetary imaging and spectroscopy of the star system you've selected as your new home.

Armed with the information in this chapter, you can make some educated guesses about which star systems are likely to contain terrestrial planets. This can save you a lot of grief, particularly if you can't afford to send off ULBI probes to gather data ahead of your starship. Imagine the heartbreak of building your ship, stuffing it to the rafters with colonists and supplies, making the long journey, then arriving at your new home only to find there are no planets you can live on. Imagine how the colonists will feel about a leader who can't make intelligent decisions. Imagine the intense discomfort of being tarred, feathered, then ejected out of the nearest airlock without benefit of a spacesuit.

If you want to know how you can bend your new planet to your will, read the next chapter.

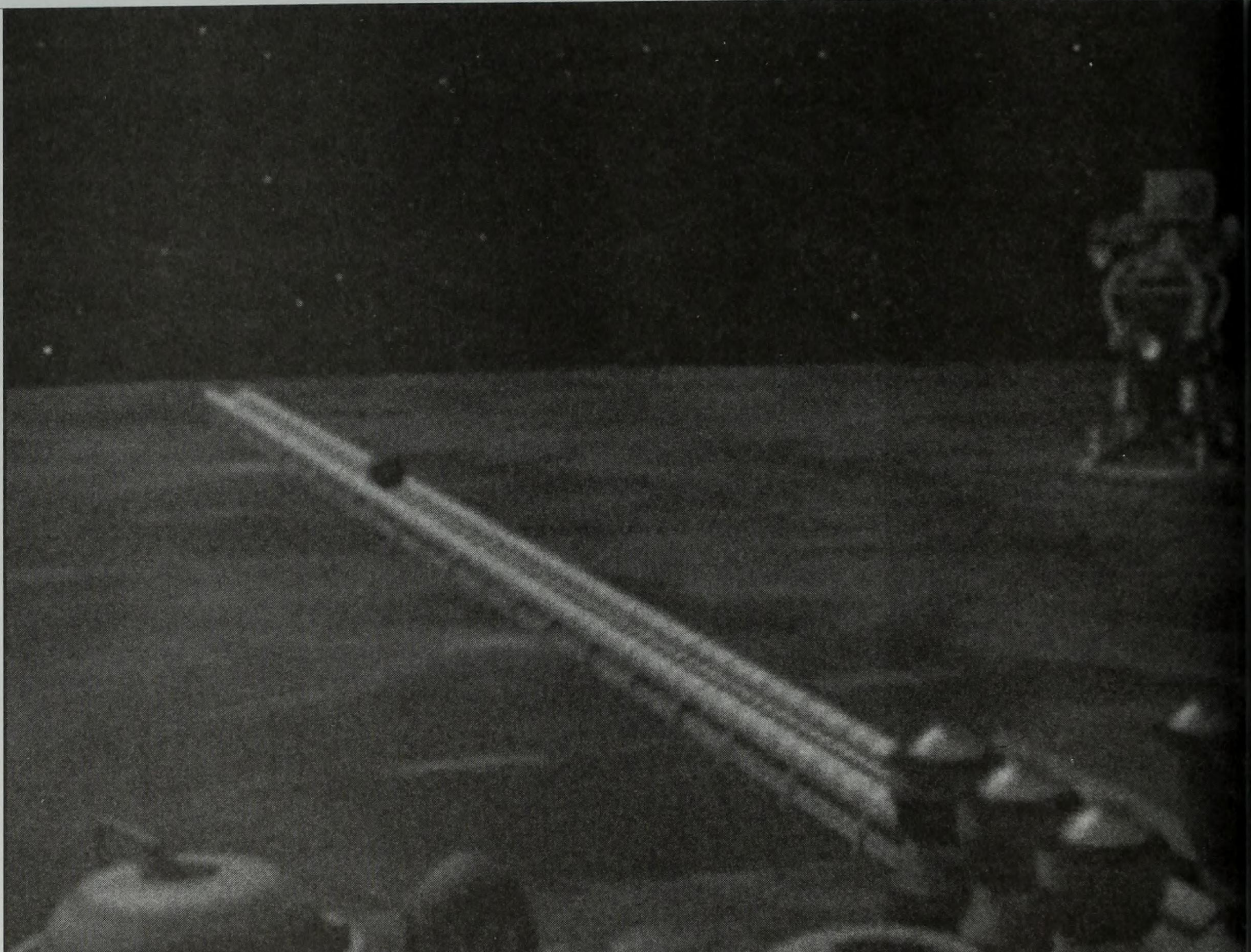
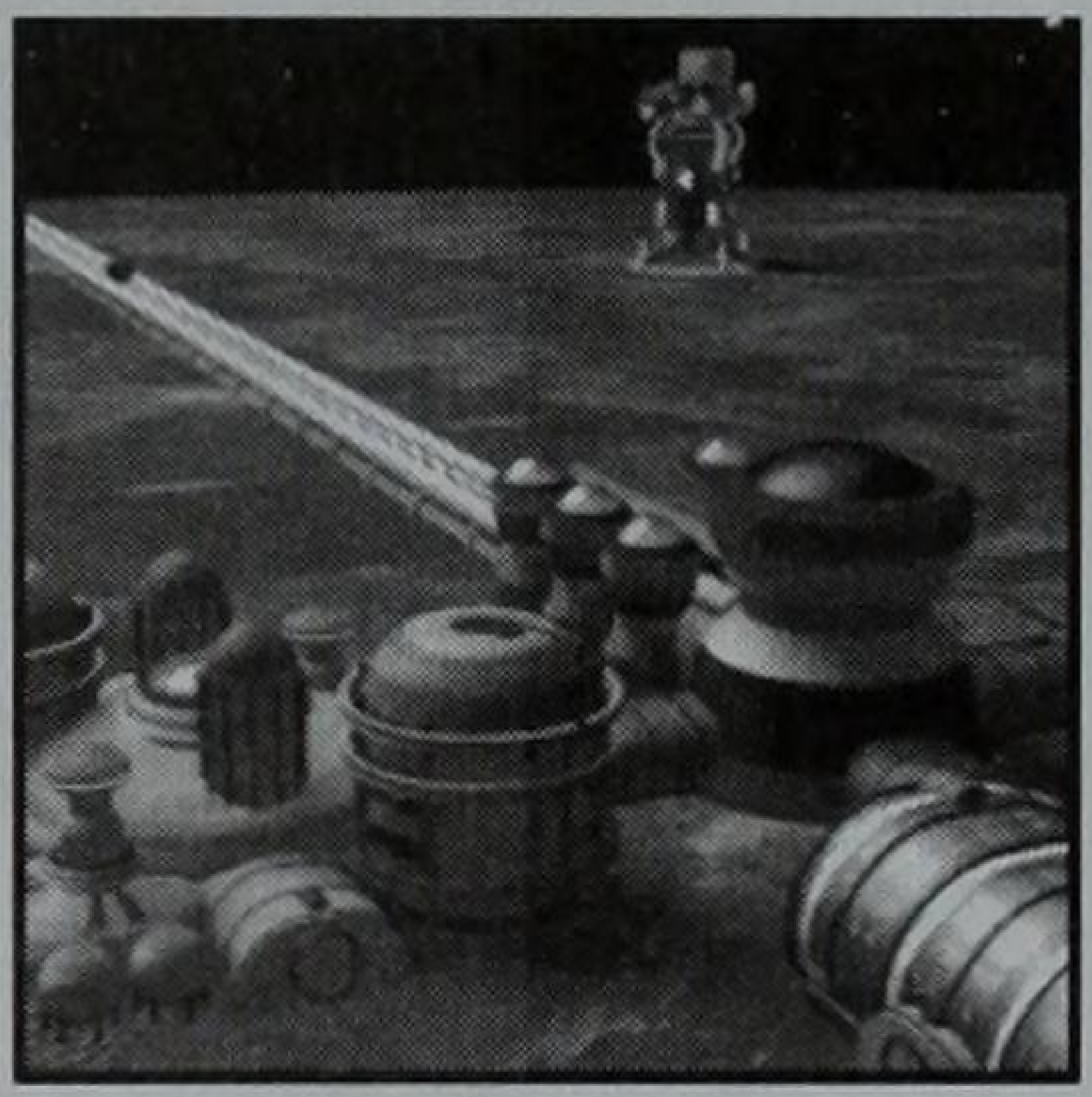


Figure 23-1 A Mass Driver launching a load into orbit.

23



Terraforming

Everybody talks about the weather, but

nobody does anything about it.

Attributed to Mark Twain, but actually written in a *Hartford Courant* newspaper editorial by Charles Dudley Warner on August 24, 1897

As we understand more about the biological and chemical processes that make our planet a great place to live, scientists are considering what it would take to make other planets conducive to life as we know it. The process of making an Earth-type environment on another world is known as *terraforming* or *planetary ecosynthesis*. Personally, I have enough trouble keeping house plants alive, so I won't be trying to terraform other planets any time soon. However, on the off chance that you're better at this sort of thing than I am, or if you're just interested in how the process might work, I'll do my best to explain it for you in this chapter.

Bending a Planet to Your Will

Thinking in terms of the Solar System, the best candidate for terraforming activity is Mars. Because the distribution of planetary types in *Outpost* is based on the reasonable assumption that our local bodies are typically formed planets and satellites, Mars-type planets are common in the various star systems of this game. Because most terraforming studies deal with Mars, it will serve as our example planet in this discussion.

Considering how little we know about the mechanics of our own climate, it may seem a bit early to be talking about planetary engineering. The ability to modify wind patterns and rainfall to improve agriculture on Earth may be the first step in learning how to alter a global ecology, but scientists have talked about projects on a much larger scale. Some proposed projects would:

- Thin the atmosphere of Venus and cool the planet's surface to allow the formation of oceans
- Enhance the atmosphere of Mars, turning the red skies blue and making rain fall on the parched surface
- Mine the asteroids as raw material to build orbital colonies and provide resources for planetary colonies

In *Outpost*, extensive research can lead you to the development of terraforming facilities. A Stage 1 terraforming facility is shown in Figure 23-2. By using a long-term atmospheric modification method that I'll explain later, these facilities allow you to make a gradual change to your planet's environment that will make life more comfortable for your colonists. This improvement in the quality of life will have a big effect on the morale of your population. Now that I've convinced you that terraforming is worth the effort, you need only know where you can do it and how to go about it.

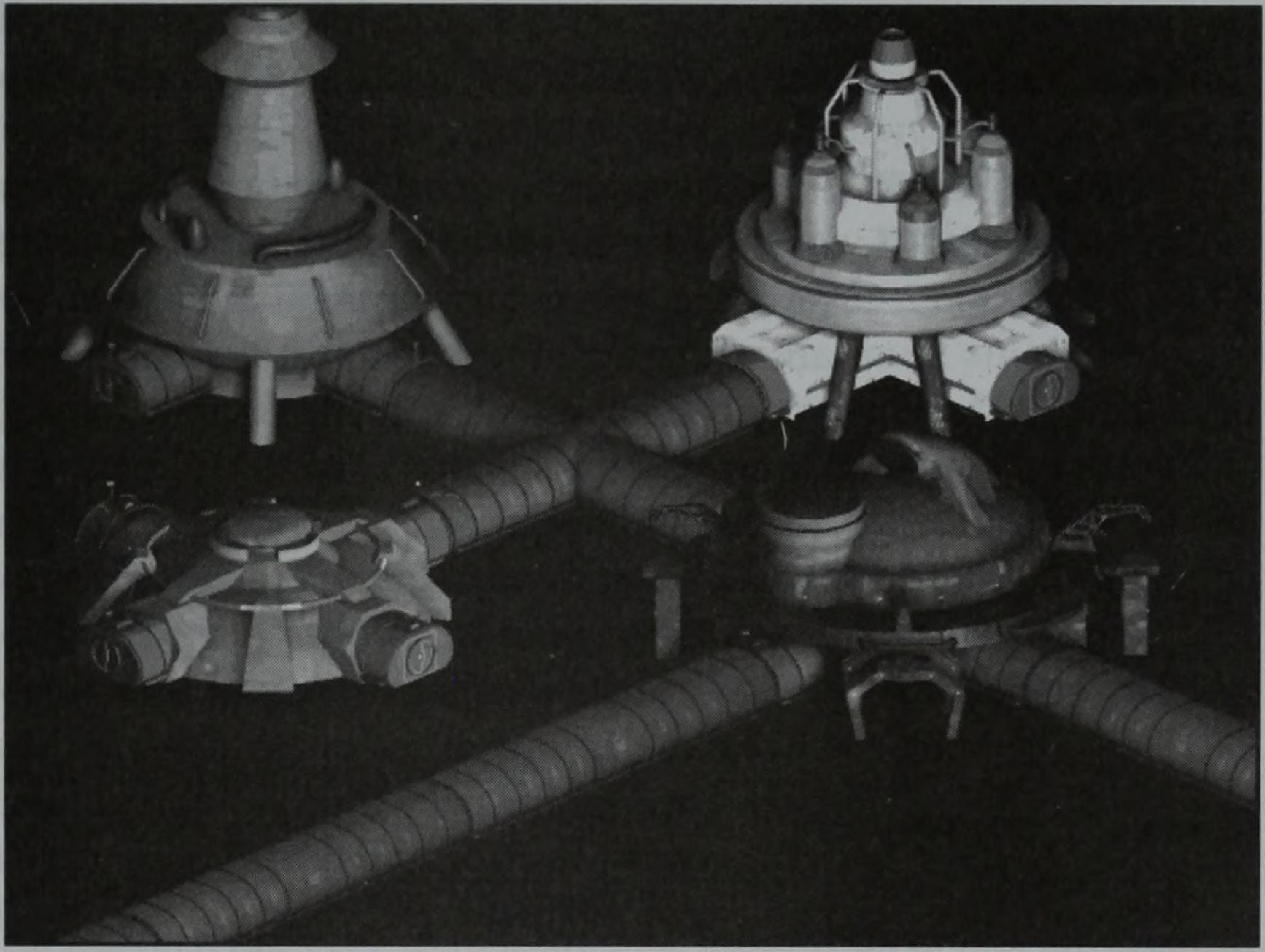


Figure 23-2

Stage 1 terraforming facility (top right) connected to colony

Requirements for Terraforming

As we know from the history of the Earth and studies of other planets, major climate changes are periodic events in every planet's life. Earth had its ice age, Mars had a period when liquid water flowed on the surface, and the volcanic terrain of Venus may have been covered with oceans underneath a thinner atmosphere. There are many reasons why these climatic changes may have occurred, but planetary scientists suspect that some minor trigger was able to change the whole environment. Finding such a trigger, an ecological instability or environmental advantage, could be the key to changing an entire planetary biosphere.

The closer a planet's physical characteristics are to those of Earth, the easier would be the process of terraforming. The rate of rotation and tilt of the axis control the planet's seasons. The size and gravity of the planet determine whether an atmosphere can be maintained, rather than drifting off into space. To build a proper biosphere, the planet also needs the presence of three organic compounds that are the basis of life as we know it: water, carbon dioxide, and nitrogen. Water is necessary for the biochemical processes of life. Oxygen is formed out of carbon dioxide through photosynthesis. Nitrogen is necessary to build proteins and other biomolecules. If there are sufficient amounts of these elements, there's a chance that the planet's environment can be modified to support life.

Long-Term Terraforming

Mars is a small, cold, dry planet with a thin atmosphere that does little to block the incoming ultraviolet radiation. Maintaining a breathable atmospheric pressure in the lower gravity would require about three times the atmospheric mass of Earth, but this would be an advantage because the thicker atmosphere would be warmer, compensating somewhat for the planet's greater distance from the Sun. All of the elements necessary to support life have been found in some form, even if they are locked in the soil as permafrost or frozen into the polar icecaps.

If Mars were warmer, the frozen water and carbon dioxide would be released into an atmosphere about 10 percent as thick as Earth's. If the atmosphere were thicker, various heating mechanisms, such as advective heating and the greenhouse effect, would raise planetary temperatures and melt most of the icecaps to form a less hostile environment. If we can start the process, the planet's climate could be switched from one stable state to another. A thick atmosphere leads to warmth generated from the greenhouse effect, which maintains the thick atmosphere, which maintains the warmth. Once this pattern has been established, the next step would be to convert the atmospheric carbon dioxide and soil nitrates to the desired oxygen and nitrogen mixture. Although biological systems are not very efficient at converting energy to biomass, the only known mechanism that can change a planetary atmosphere is life.

Several methods for terraforming Mars have been studied, but we'll just look at three of them here.

Bioterraforming

In 1976, NASA's Ames Research Center sponsored a study on terraforming Mars. Even with the low air pressure and intense ultraviolet light, the study suggested that a genetically engineered form of plant life might be able to survive unprotected on the martian surface. They also showed that bioterraforming might be possible without the aid of genetic engineering. A combination of mats of blue-green "algae"—actually a form of bacteria—and lichen might be able to survive today's martian conditions.

Lichens can grow on or in stone, excreting acids to dissolve the rocks' outer layers and break them down. They can also protect themselves from ultraviolet light by incorporating sand into their outer skins. Algae could use a thin layer of sand as their ultraviolet shield and still manage to maintain photosynthesis, building up the soil and combining nitrogen into it. Their growth would be slow and they would produce oxygen only a few hours a day. Computer simulations demonstrated that this method could take more than 100,000 years to produce the minimum amount of oxygen required for breathing, but the quantity of carbon dioxide in the air would still be too high for humans. Large amounts of water vapor, released through other methods, would be required to remove the excess carbon dioxide. The *Viking* lander also demonstrated that adding water to the martian soil generates free oxygen, a discovery that could speed up the terraforming process.

It's All Done with Mirrors

Mars receives about 60 percent as much solar energy as the Earth. To heat up the martian polar caps, highly reflective metalfoil mirrors, which are very thin, light, and thousands of feet long, could be placed in a martian orbit that would focus 20 percent more solar energy onto the poles. This type of mirror has been tested in Earth orbit. The heating effect could be enhanced by darkening the surface of the polar caps to increase the amount of solar energy absorbed. Because more heat is reflected by a whiter surface, over 75 percent of the sunlight hitting the martian icecaps is currently reflected. As on Earth, the amount of sunlight at the poles is already reduced by the planet's inclination to the sun. To darken the icecaps on Mars, black soot could be spread over them. The martian moons, Deimos and Phobos, are composed of dark, carbonaceous material. A mass driver established on Deimos could launch buckets of this black powder down onto the polar caps. Figure 23-1 shows a mass driver in operation. Because this carbonaceous material is rich in organic compounds, it would also provide fertilizer. The warming of the polar caps would release the carbon dioxide, warming the atmosphere still further, releasing more carbon dioxide, and so on.

Terraforming Factories

Using computer simulation, NASA scientists have demonstrated another method for terraforming Mars, using current technology. Although the carbon dioxide content of the martian atmosphere has only about 1 percent of the pressure of Earth's atmosphere at sea level, there are probably reserves of carbon dioxide within the soil sufficient to thicken the atmosphere to the point where its pressure would be about 30 percent that of Earth's. As we've already mentioned, the way to get this gas to emerge is to heat the planet. Each martian year, the planet warms and cools as it cycles between its nearest and farthest positions from the Sun. This causes the atmospheric pressure to vary seasonally by plus or minus 20 percent.

Because we can't move Mars to a warmer orbit, we could set up factories on the martian surface to produce greenhouse gases such as chlorofluorocarbons (CFCs) at about the same rate they are currently being produced on Earth—a production rate that would require an electric power capacity about equal to that of Chicago. This would warm the planet enough to release large amounts of carbon dioxide from the soil. This carbon dioxide would intensify the greenhouse effect being created by the CFC gases, warming the planet faster. These CFCs would be specially formulated so that they wouldn't stop Mars from developing a thick ozone layer.

As the planet's temperature rises, the water frozen into the soil as permafrost would begin to melt, and it would flow out into the dry riverbeds of Mars. Water vapor is also a very effective greenhouse gas, so the reappearance of liquid water on the martian surface would add to the avalanche of self-accelerating effects warming Mars. Once again, *Viking* demonstrated that adding water to the martian soil produces oxygen. Over several decades, Mars could be transformed from its current dry and frozen state into a warm and moist planet capable of supporting life.

Humans would not be able to breathe the air of the transformed Mars, but they would no longer need space suits to survive there. Instead, they could travel freely in the open wearing ordinary clothes and a simple scuba-type breathing gear. However, because the outside atmospheric pressure will have been raised to human-tolerable levels, it will be possible to build inflatable dome tents containing breathable air. On the other hand, grasses and shrubs could thrive in the carbon dioxide-rich outside environment and spread rapidly across the martian surface. These plants could be followed by flowers, trees, and food crops. Over the course of centuries, these plants would introduce oxygen into the atmosphere of Mars. After the oxygen concentration rose above the limit for respiration, invertebrates and insects could survive. Later, reptiles, birds, and mammals would complete the ecological system. Eventually, the day would come when the domed tents would no longer be necessary and humans could freely roam the martian surface without scuba gear.

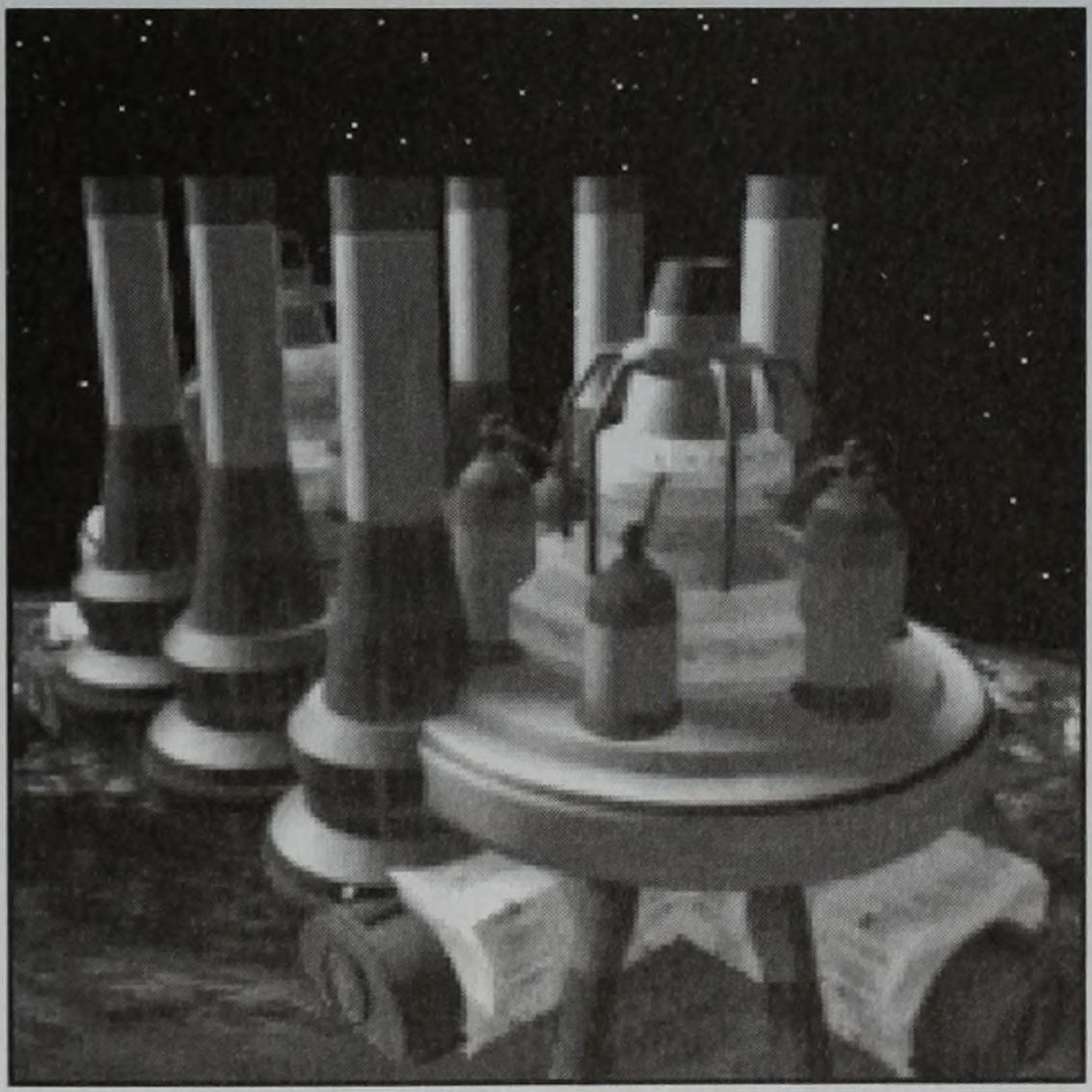
My World and Welcome to It

In *Outpost*, terraforming factories, such as the one shown in Figure 23-3, and genetically engineered bioterraforming can be used to transform the atmospheres of appropriate planets. Because this is a major step in the development of your civilization, it will demonstrate to your population that you have led them well beyond the state of merely trying to survive. Morale will improve, which means scientific research will accelerate, more babies will be born, and factory production will increase. Your popularity will soar, reminding everyone that you are the best person to lead them into the future. If you can tame a planet, you can certainly handle the management of your colonies.

Now that you've learned the basics of planetary engineering, let's consider the simpler topic of why big rocks can fall out of the sky and hurt you. The next chapter will explain why flashy comets eventually sneak around as dark asteroids, the impending threat to Earth, how to detect possible threats, and what you can do about massive incoming objects that might land on your house.

Figure 23-3

Stage 2 terraforming factory



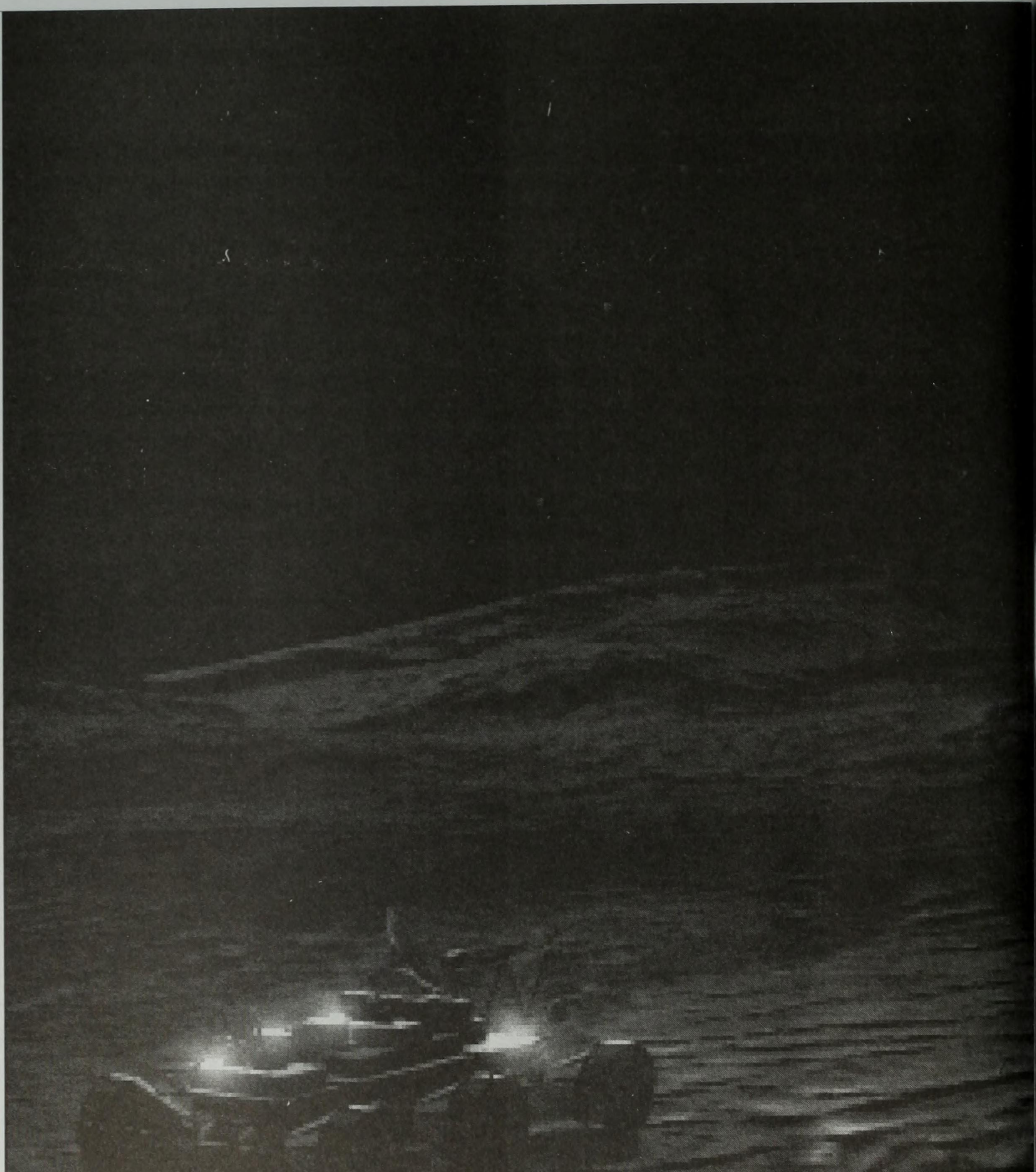
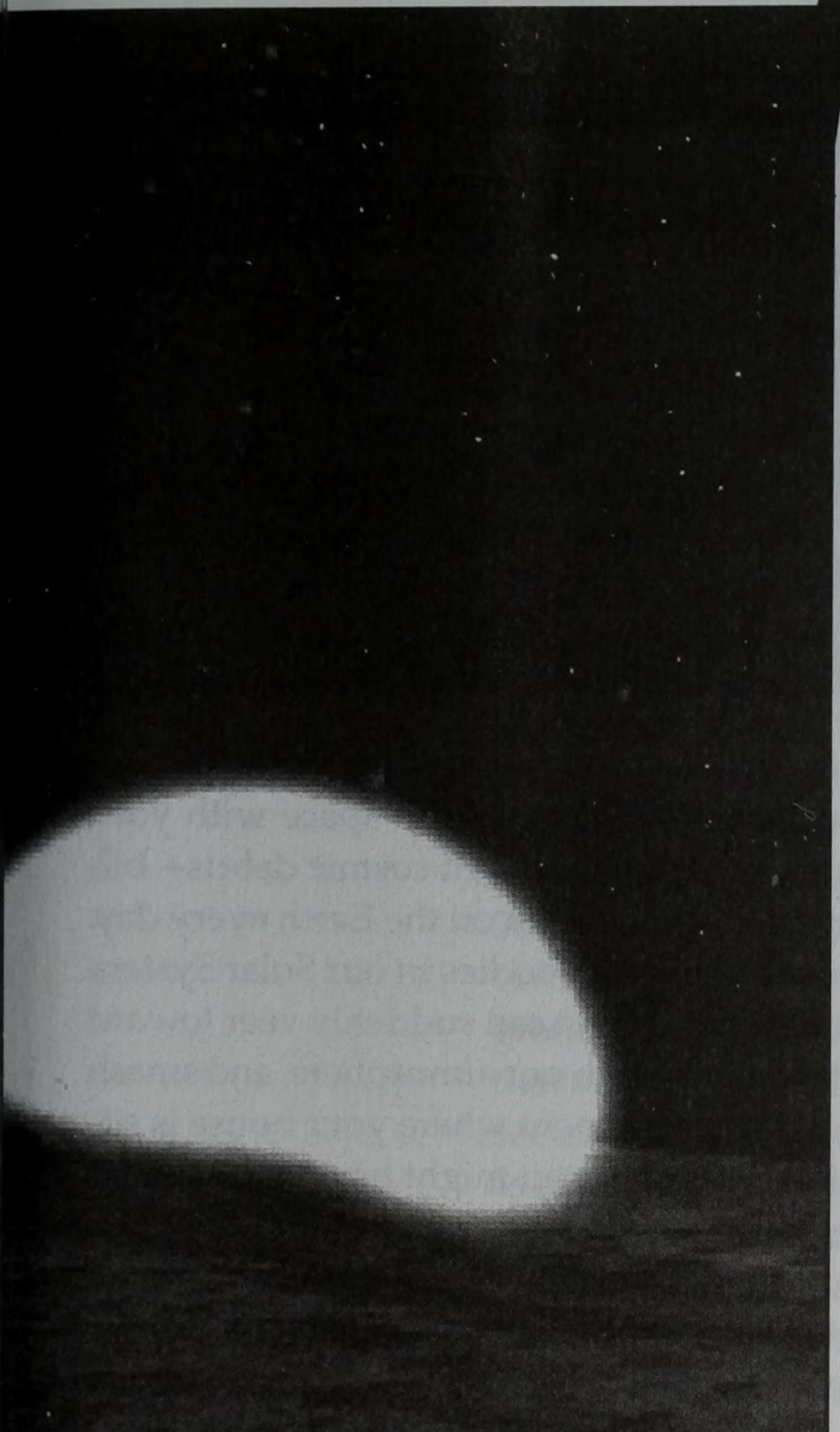


Figure 24-1 A roboexplorer watches a meteorite strike the colony.



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The Sky Is Falling

Lo! from the dread immensity of space,
Returning, with accelerated course,
The rushing Comet to the Sun descends;
And, as he shrinks below the shading earth,
With awful train projected o'er the heavens,
The guilty nations tremble.

James Thomson, 18th century poet

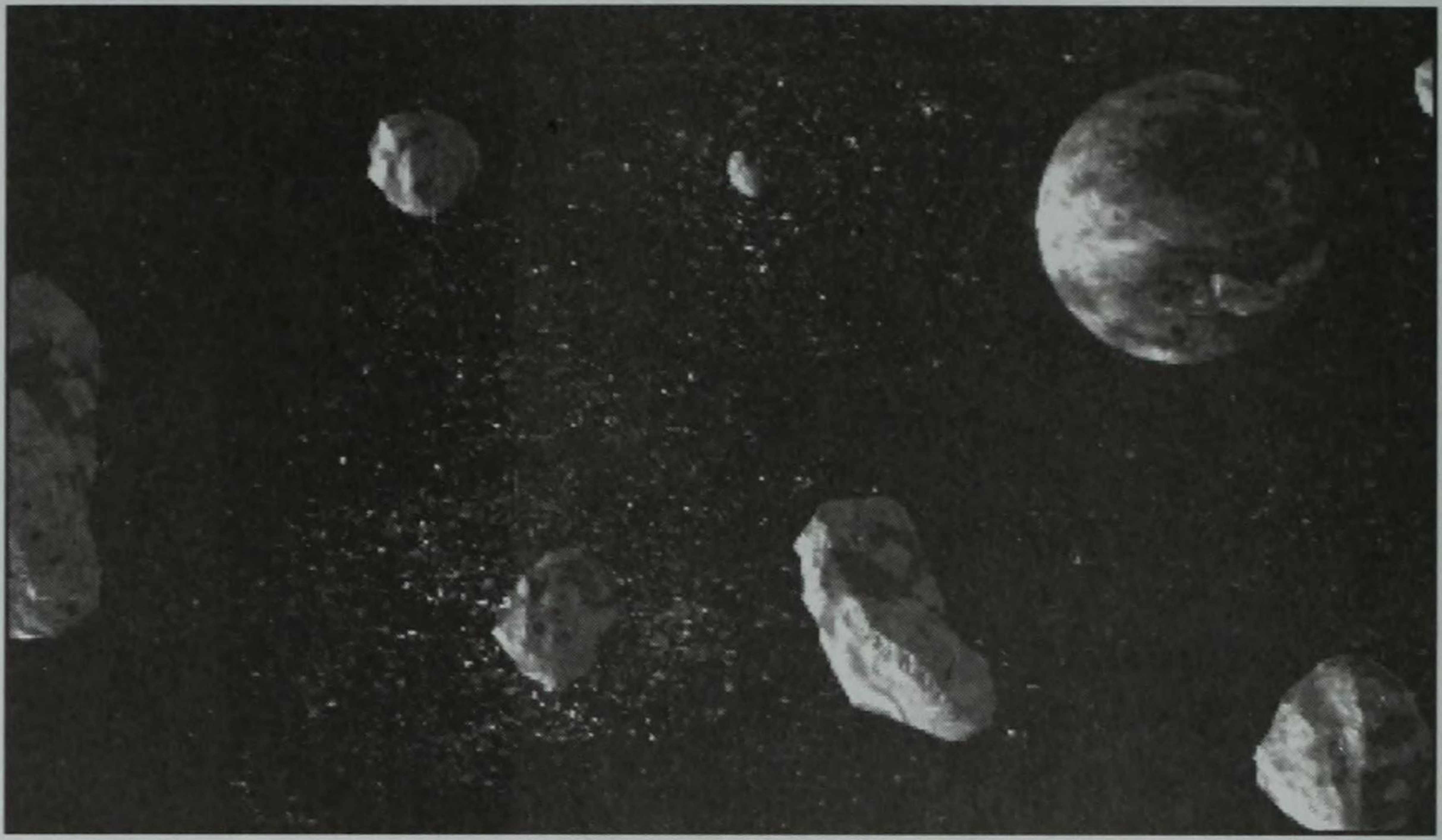


Figure 24-2

Kind of makes you stop and think, doesn't it?

Is there a giant rock hurtling toward you from space with your name on it? Maybe. As much as 1,000 tons of cosmic debris—billions of microscopic particles—rain down on the Earth every day. Understanding the nature of the small bodies in our Solar System will show you why an inanimate object can suddenly veer toward Earth, survive its fiery descent through our atmosphere, and smash your house, not to mention the continent where your house is sitting. This chapter also tells you why you might have to deal with this sort of threat more than once. There is no attempt to explain why your insurance company won't pay for a new house after your old one has been destroyed by a meteorite; that's a topic beyond human comprehension.

Chicken Little Was Right

Researchers have estimated that your individual chance of being killed by an asteroid impact is 1 in 6,000. This is about the same as your chance of being killed in an earthquake. Large asteroid impacts may not occur as often as earthquakes, but they can make up for this lack by killing many more people when they finally arrive. As with any other sort of infrequent natural disaster, this type of threat tends to be ignored until it happens. Although the average person in California is somewhat prepared for earthquakes and is aware of the threat, the average person in Missouri, where the last major earthquakes occurred in 1812, may not even be aware of the risk. Denial of the threat will not diminish the result of a major quake in Missouri killing tens of thousands of people and causing property damage in the tens of billions of dollars. The general public has the same indifference toward hurricanes, floods, tornadoes, and volcanic eruptions. Consider the television news, where you might be watching people float around on top of their houses during a major flood. You might wonder why they chose to live in a place where floods are known to wash through the area every 30 to 100 years. Fifty years from now, we might also wonder why so much of the Earth's population chose to die instead of doing something about detecting and diverting asteroids that could have such an impact on the Earth's surface.

Before we go any further, let's be clear on the terminology. If a near-Earth object displays a coma—a "head"—or a tail of dust and gas when viewed through a telescope, it is classified as a *comet*. If you can't make head or tail of it, then it's classified as an *asteroid*. Now, after a comet has made a few swings past the Sun, it may become covered with dust that prevents it from forming a coma or a tail, so we might have called it a comet at one time, but it's an asteroid now. Confused? If an object in space is smaller than about 30 feet in diameter, it's not an asteroid, it's a *meteoroid*. If it survives passage through the Earth's atmosphere and strikes the ground—which is actually more likely to happen with an object that's larger than 30 feet in diameter—then it's a *meteorite*. If you see a streak of light in the night sky, it's a piece of dust burning up as it enters the atmosphere, sometimes known as a "shooting star," but technically called a *meteor*. If you see a lot of those streaks of light in a short period, it's a *meteor shower*. Had enough?

But wait! There's more! Asteroids are also categorized by their orbits. *Amors* are asteroids that cross the orbit of Mars and approach the orbit of Earth. About 10 percent of the Amors have orbits that evolve into Earth-crossing orbits over short periods of time, perhaps hundreds or thousands of years. *Apollos* are asteroids that cross the Earth's orbit, some of which get closer than the orbit of the Moon. Apollos are some of the closest objects to Earth. *Atens* are objects that orbit primarily within the Earth's orbit, although they may cross Earth's orbit at their farthest point from the Sun.

Okay, that's enough terminology.

Near-Earth Asteroids

About 200 near-Earth asteroids (NEAs) larger than three-tenths of a mile in diameter have been discovered. Estimates range from 5,000 to 10,000 objects of this size, which means only 1 to 2 percent of them have been detected. Of a possible 2,000 objects larger than six-tenths of a mile in diameter, only about 100 have been tracked. The largest of the known NEAs, 1036 Ganymed, not to be confused with Jupiter's moon Ganymede, is 25 miles in diameter. Of all the near-Earth objects, up to half of them could be burned-out comets that have come a long way just to hang out around the inner Solar System. The short-period comet turned asteroid in *Outpost* is this type of wandering vagrant, having disguised its true identity as the comet Vulcan, with a cloak of black carbonaceous soot.

Comets can lead long and interesting lives, although the final phases of their existence are not well understood. In 1950, Dutch astronomer Jan Oort suggested that a cloud of comets surrounds the Sun at a distance of 20,000 to 100,000 astronomical units. Affected by the gravity of nearby stars, comets are pulled out of this *Oort Cloud* on a regular basis and sent on long-period orbits around the Sun. About three comets are discovered annually near the Earth, so Oort estimated there must be about 100 billion comets in the cloud. In 1951, Gerard Kuiper proposed a second possible source of comets orbiting the Sun just beyond the orbit of Pluto. This comet reservoir, now known as the Kuiper Belt, is about 50 astronomical units distant. Recent discoveries lend support for the existence of this nearby source of short-period comets.

Short-period comets, with orbits of less than 200 years, were thought to originate from the long-period comets. Through interaction with the gravities of Jupiter and other planets of the Solar System, it was thought that some long-period comets were deflected into short-period orbits. It is now believed that long-period comets, which enter the Solar System from random directions, come from the Oort Cloud whereas short-period comets, which orbit close to the ecliptic plane, originate in the Kuiper Belt. It seems that gravitational interactions with planets have little effect on long-period comets.

Some short-period comets generate streams of dust particles that penetrate the Earth's atmosphere as meteor showers. If a comet passes close enough to the Sun, it can also break into fragments, continuing on as a group of smaller comets. Small comet nuclei pass Earth's vicinity about 10 times less often than asteroids of the same size, but the impact velocity with Earth is 3.3 times higher for comets. Generating more bang for the buck, comets create the biggest craters. About 200 short-period comets have been discovered, representing only a small portion of the total population.

Following the "dirty iceberg" model, astronomers of the 1970s expected comets to have bright white surfaces like icebergs, helping to distinguish them from "rocky" asteroids. During the 1980s, spacecraft images proved them wrong. Comets are black. In fact, all of the interplanetary bodies, such as the Trojan asteroids, Hilda asteroids, and the small captured satellites of Jupiter, have black surfaces thought to be rich in carbonaceous minerals. This carbonaceous "soot," rich in organic compounds, reflects as little as 2 percent of the sunlight that strikes it. In the cold outer Solar System, ices were added to the mixture as bodies formed, but the black soot was such an effective coloring agent that any light color in a "dirty ice" combination was overwhelmed. This is the sort of problem that creates such confusion over the identities of comets and asteroids.

Asteroid Names

1992DB, 1991BA, 433 Eros, 1 Ceres, 15 Eunomia, 851 Wladilena, 449 Hamburga—where do they get those wacky asteroid names? On discovery, an asteroid is given a temporary designation consisting of the year of discovery and two letters. Each month is divided in half and assigned a letter, so the first letter indicates the half-month of discovery. The first half of January is an "A." The second half of February is a "D." The second letter of the temporary designation gives the order of discovery. So, an asteroid name such as 1992DB means it was discovered in 1992, in the second half of February, and it was the second asteroid discovered during that half of the month. On average, astronomers find two new asteroids per month.

When a new asteroid has been tracked long enough that its orbital path is known, it receives a permanent number. The person who discovered the asteroid is then allowed to name it. 1982DB, now known as "Nereus," was discovered as part of the Planet-Crossing Asteroid Survey, a search started in 1973 by Eleanor Helin and Gene Shoemaker to find Earth-approaching asteroids and comets. It joins about 5,000 other asteroids whose names refer to such diverse entities as Greek and Roman gods (2 Pallas, 3 Juno, 4 Vesta, 1682 Apollo), an airline (2138 Swissair), a dining establishment (2038 Bistro), and the Beatles (4147 Lennon, 4148 McCartney, 4149 Harrison, 4150 Starr).

The Sheep Look Up

To borrow a novel title from John Brunner, the sheep looked up over Oregon on August 10, 1972. A near-Earth asteroid the size of a small house was undetected until it burned through Earth's atmosphere for 101 seconds on a bright and sunny day. Weighing in at 1 million tons, the asteroid's fireball and its long vapor trail were photographed by an alert tourist at Grand Teton National Park as it passed overhead at 33,000 miles per hour. Sparing the Earth from its destructive force—five times more powerful than the bomb that destroyed Hiroshima—the asteroid raced over 915 miles of the Earth's surface before it returned to space. A slight change in its orbit around the Sun would have made 1972 a very memorable year.

Most asteroid discoveries are made with short-focus, wide-field telescopes and photographic equipment. When an object is found, observers using different methods move to confirm the sighting. This can be accomplished with long-focus, narrow-field telescopes or charge-coupled devices (CCDs). CCDs are electronic detectors that are much more sensitive than standard photographic equipment. Large radar dishes, such as the 1,000-foot antenna at Arecibo, Puerto Rico, can also help confirm the sighting and provide detail on the object's orbit. The new asteroid's position is also checked against a catalog of asteroid and comet observations to determine if the object has been sighted in the past. If these "prediscovery" data exist, they can be used to calculate an orbit that is much more accurate than would be possible with the discovery observations alone.

When the new object's trajectory has been calculated, it is said to be "secure" and the discoverer can assign a permanent name to the object. Researchers are then able to take the time to determine the object's physical characteristics. Size and mass would be of particular importance in the case of an object due to collide with Earth, because these factors would help determine how much damage would occur. Optical and radar observations can also be used to estimate the shape, reflectivity, and rotation period of the object.

In 1991, NASA sponsored the Near-Earth Object Detection Workshop. The study concluded that there are no existing systems or practical detection plans that would provide an early warning of objects about to strike the Earth. Even the radar systems designed to detect missile launches from the United States and Russia are not powerful enough to detect an incoming asteroid on an unknown trajectory.

Proposals for incoming asteroid intervention range from thorough studies of the Earth-crossing object population to launching missiles at objects known to be on a collision course with our planet. Probe missions, which include flybys, rendezvous missions, and sample-return missions, can also provide data to aid intervention strategies, although this approach would require many years of warning.

An inexpensive detection system has been proposed that would search the skies for the largest objects that might threaten the Earth. This proposal involves a series of ground-based telescopes working together that could track such objects many years before impact. This network would involve an initial investment of 100 million dollars. However, even with a comprehensive search program, poor observation, weather, and the rapid movement of near-Earth objects would still make it difficult to detect all of the possible threats.

Let's consider an optimum situation in which we have several years' worth of warning that a large asteroid is on a collision course with Earth. What could we do about it? Assuming the strike zone could be projected with a reasonable degree of certainty, evacuation of local regions of the Earth's surface would be pointless for such an object, because the impact would have global consequences. With an investment of several billion dollars, it would be possible to develop a space probe armed with a nuclear weapon to try and divert the asteroid's path. In the 1960s, studies suggested that high-yield hydrogen bombs could perform this function, although there is the possibility that the explosion could fragment the asteroid and increase the threat. Instead of one large object, there could be several pieces whose trajectories were even harder to predict. Of course, current detection methods would not be able to provide us with several years' worth of early warning. No hardware has been built to intercept such an asteroid and deflect its path, although existing launch vehicles could start the probe on its journey. The money for such new programs is also not likely to be forthcoming in the near future. Note that the study involving hydrogen bombs was conducted 30 years ago, but no action was ever taken along this line of research. Projects involving more exotic methods of asteroid interception, such as the idea of attaching a propulsion system to an asteroid to divert it away from Earth, have an even smaller likelihood of receiving funding.

Possible Impacts on Your Colony

Okay, let's say you were clever enough to buy *Outpost* and leave town before the asteroid made such a big impression on your home planet. You still aren't safe. Asteroids and comets are the by-products of planetary evolution, so it's a reasonable assumption that you will find them in any other star system where planets have formed. Impact craters are the most common landform on the rocky and icy planets and satellites of the Solar System. Asteroids are the dominant bodies that cross the orbits of Earth and Mars, whereas comet nuclei are most common at the orbit of Jupiter and beyond. Orbital motion studies and photographic surveys in a recent study showed that there are about 20,000 large asteroids that make close approaches across the orbit of Mars. These objects have a 50 percent chance of hitting a planet or being thrown out of the Solar System through strong gravitational effects. If the orbits of the known Earth-crossing asteroids are a representative sample, an average of five large objects collide with the Earth every million years. About 30 comets with solid nuclei larger than 1.5 miles in diameter pass within Earth's orbit each year, of which an average of 1 in every 10 million years will strike the Earth. Comet nuclei at least 6 miles in diameter hit the Earth once every 100 million years. A similar number of asteroids and comets strike Venus, and a smaller number collide with Mars, Mercury, and the Moon. If Venus did not have such a thick atmosphere, the cratering rate by cometary impact would be about 14 percent higher than it is on Earth.

In the early history of a planet, impacts by comets can be a good thing. Cometary material that struck the young Earth delivered water and a cornucopia of complex molecules to aid the process of biological evolution. Loaded with *volatiles*—elements or compounds with low melting temperatures, such as water, ammonia, potassium, and sodium—these cometary visitors may have supplied Earth with almost all of its water. Similar deliveries were made to Venus, as well as the Moon, Mercury, and Mars, but they struck those low-gravity planets with such speed that their volatiles vaporized into space as high-temperature gases. Organic components from carbonaceous meteorites were slowed enough by the Earth's atmosphere to survive until they reached the surface, establishing a base from which life could evolve. This is all just another way to say that computer games might not even exist if it weren't for our friends, the comets. However, when a comet lands on an occupied planet, any highly evolved ape descendants who happen to be in the neighborhood tend to have negative opinions about such surprises.

To sum it all up, there's no place you can hide.

But science can show you the way to defend yourself. Research into physics, specifically optics and satellites, allows you to develop the meteorsat, shown in Figure 24-3, a fusion-powered orbital laser that can detect and destroy small- to medium-sized bodies approaching your new planet.

Of course, you'll need to build your space program back up to the point where heavy lifters can launch your satellites, allowing you to orbit your string of defensive meteorsats, but this accomplishment will protect your planet from all but the largest rocks coming your way. Every meteorsat you place in orbit will lessen the chance of an object striking your colony, as well as safeguard the system due to any of your older satellites failing from age or wear. Figures 24-4 and 24-5 show the meteorsat in action.

This chapter has shown you what kind of damage a rocky visitor from space can do to a planet. If I've done my job, I've also confused you with a maze of terminology, shown you the futility of your pitiful little life, awed you with the destructive and creative powers of asteroids and comets, harangued you once again with my cynical attitude toward public apathy regarding long-term

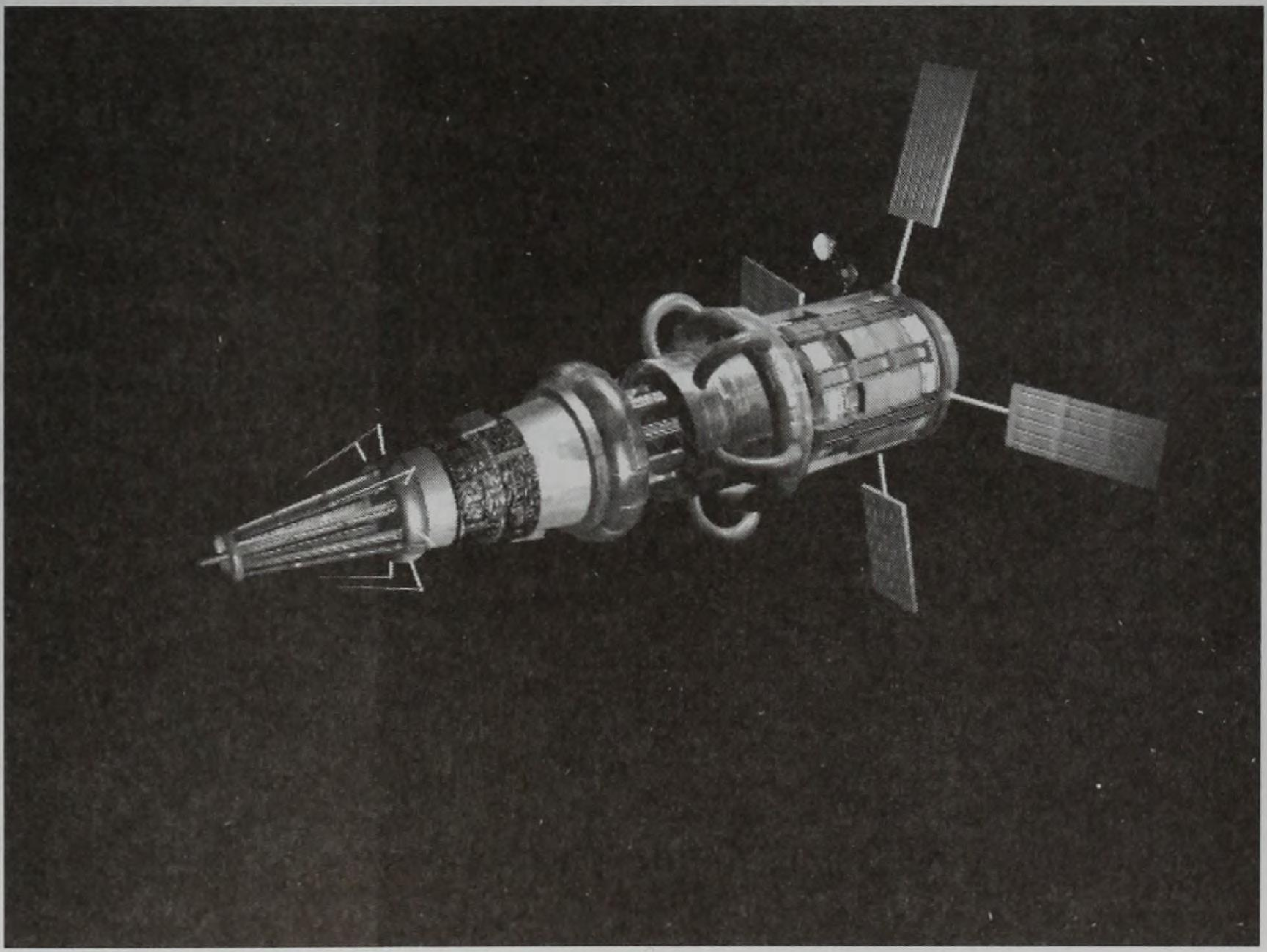


Figure 24-3

Another scientific miracle—the meteorsat

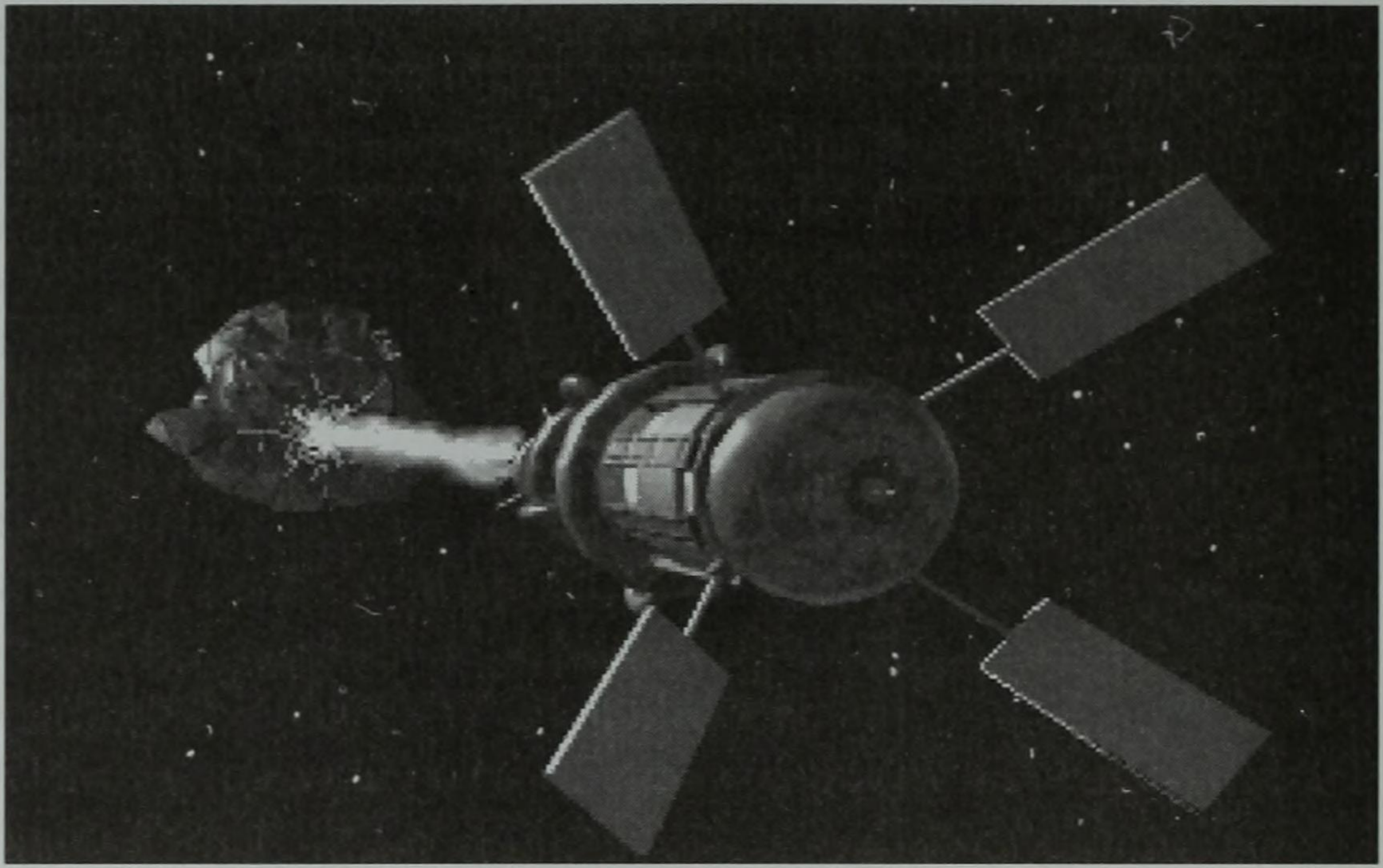


Figure 24-4

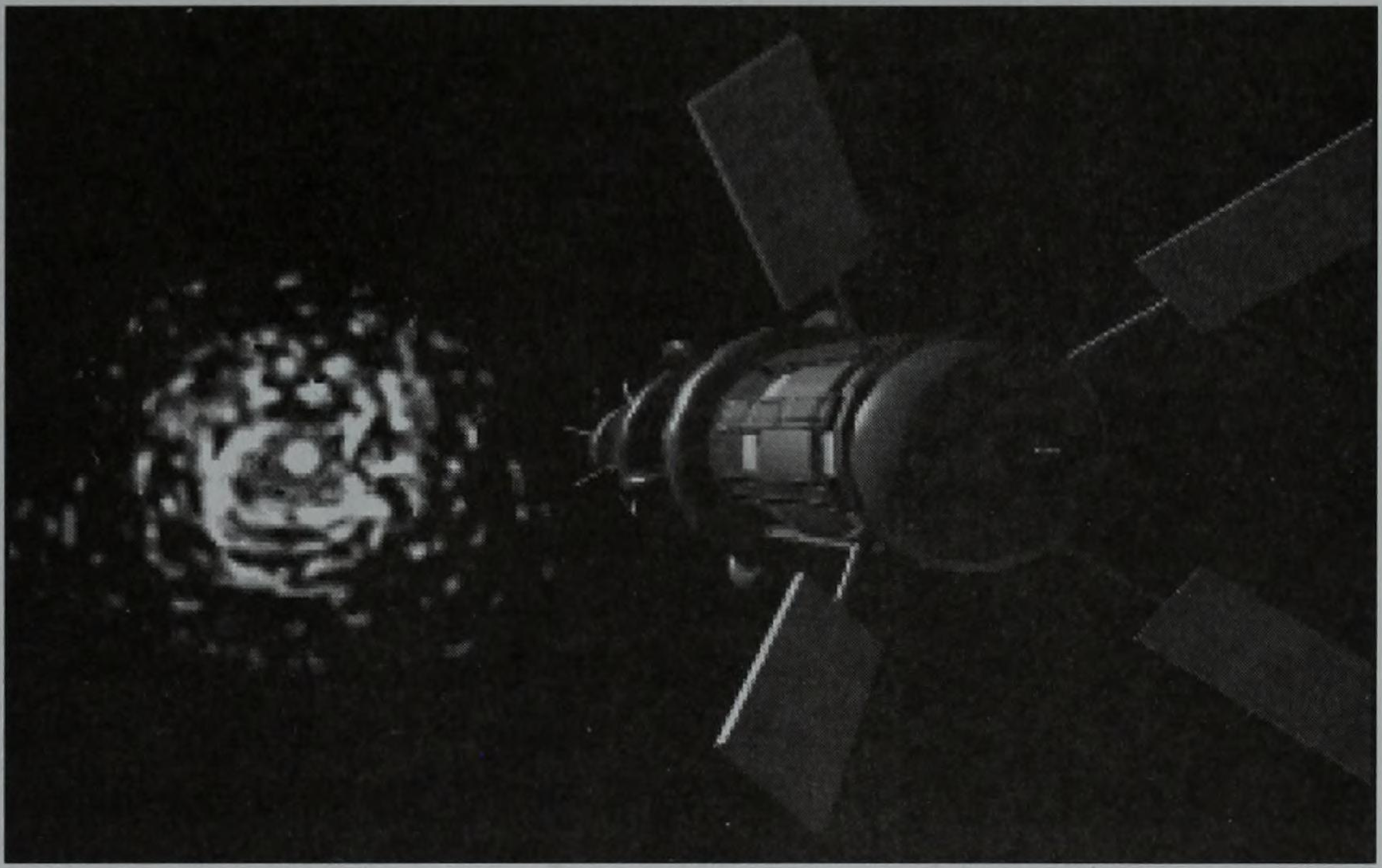
The meteorsat fires at an approaching asteroid.

threats, stunned you with more information than you ever wanted to know about comets, enlightened you about recent discoveries regarding the Oort Cloud and the Kuiper Belt, amused you with the asteroid naming system, educated you about the problems and methods of detecting objects about to strike the Earth, warned you about trying to intervene with your cosmic fate, satisfied you that not all comets are bad comets, encouraged you with a way to protect your new planet, and annoyed you with my ability to create long run-on sentences with no end in sight.

We've covered a lot so far, but I know you've been wondering about that research topic known as nanotechnology. Maybe you've heard of it before. Maybe you've heard that it's better than sliced bread. Maybe you've heard that it's going to replace sliced bread. Maybe you've heard that you can arrange individual molecules into a form that exactly duplicates sliced bread, or that you can take sliced bread and rearrange its molecules to make a digital watch. Well, maybe everything you've heard is right. Read the next chapter to find out.

Figure 24-5

Asteroid? What Asteroid?



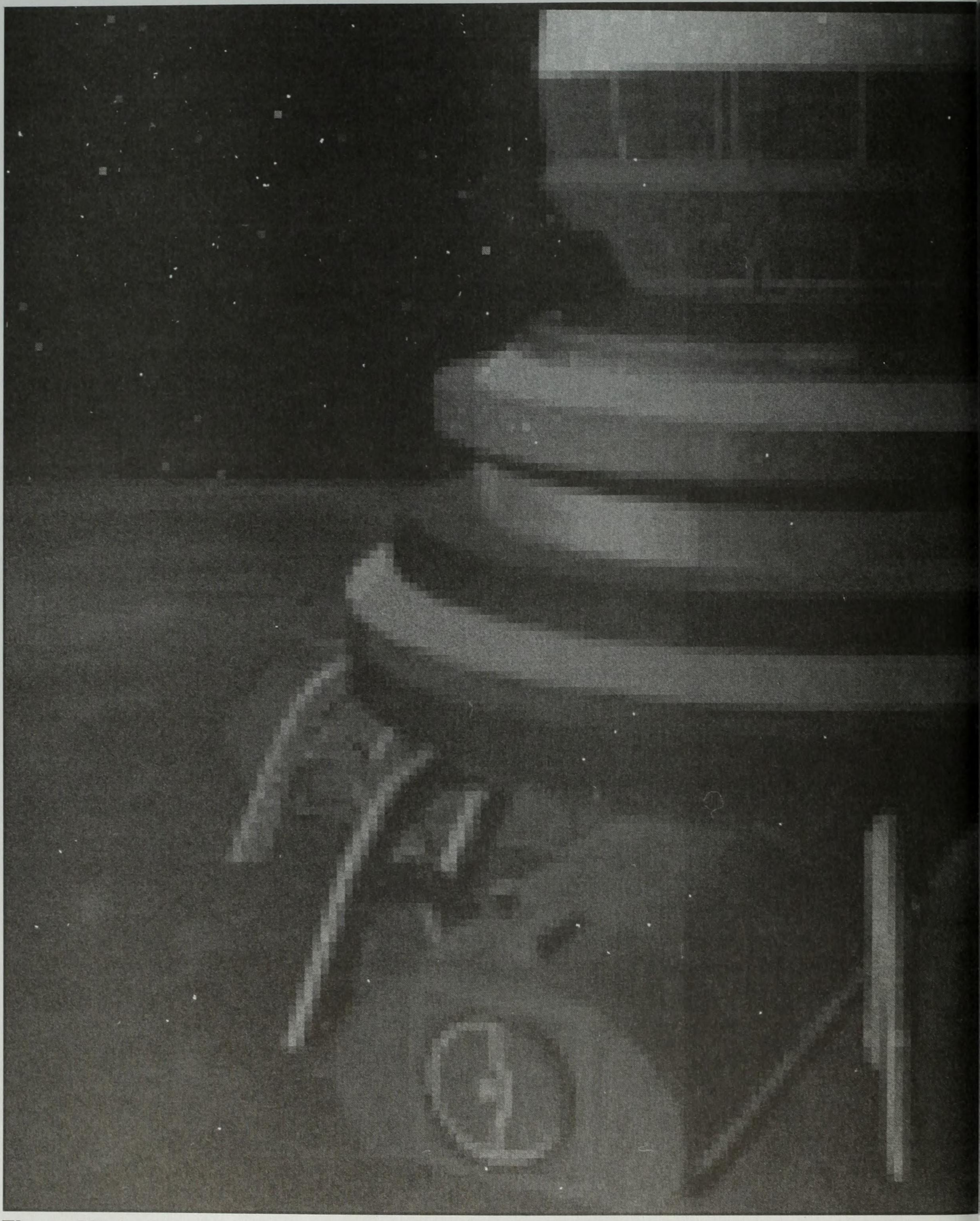
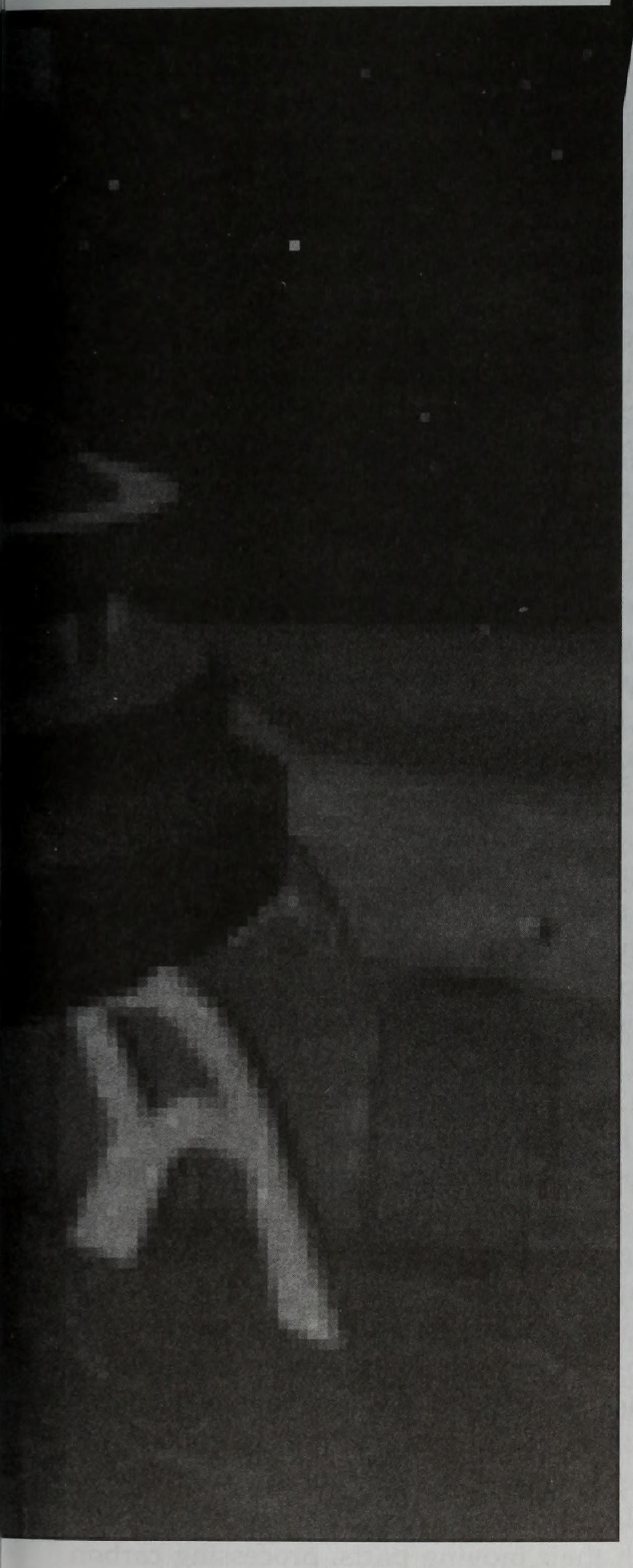


Figure 25-1 Nanotechnology facility



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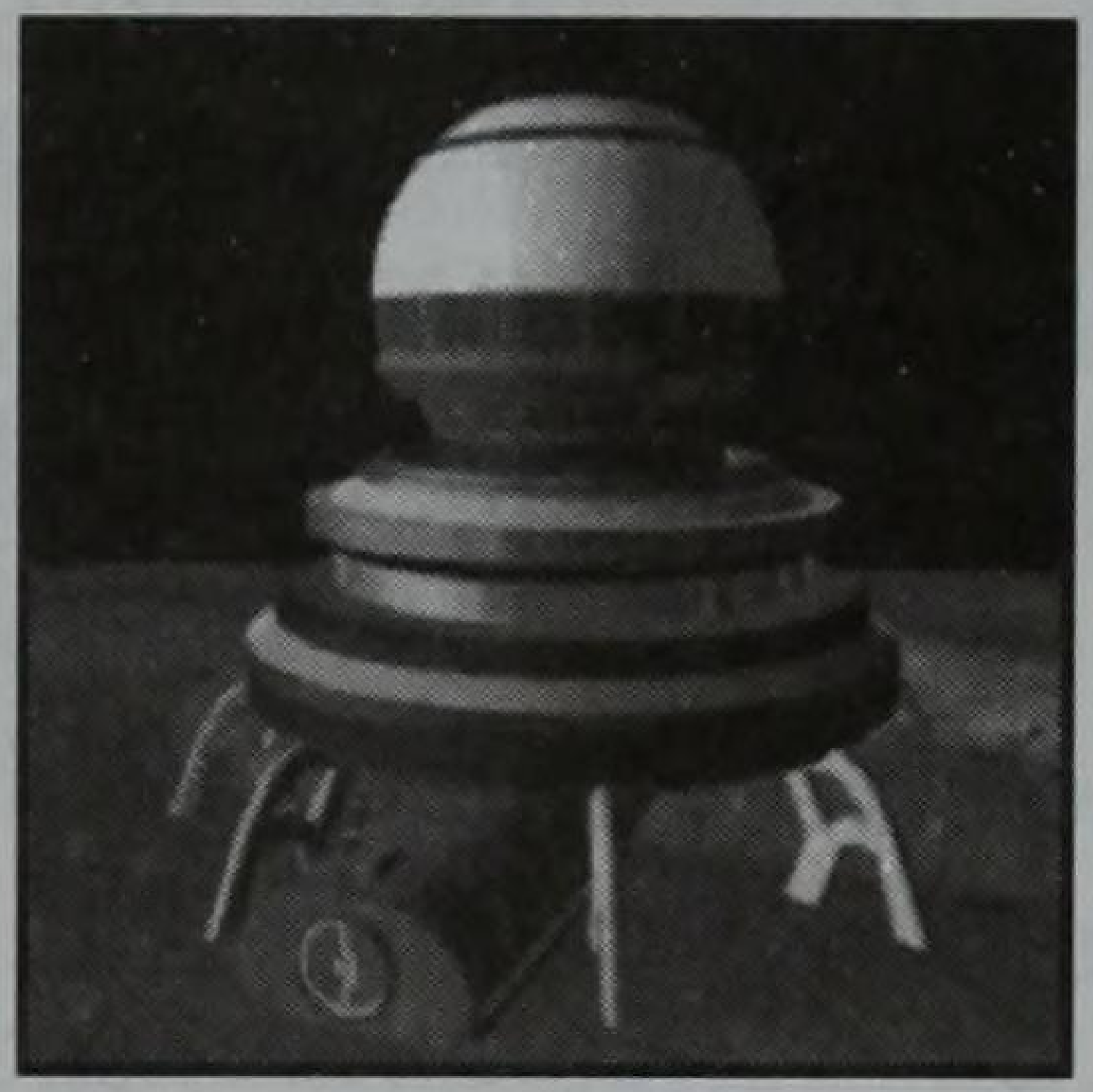


Nanotechnology

Nature uses only the longest threads to weave her patterns, so each small piece of her fabric reveals the organization of the entire tapestry.

From a lecture by Richard Feynman

Thinking small isn't always a bad thing. The problem with small-minded people is that they don't think small enough to do any good. It takes a big mind to think really small. So, let's talk about atoms. If you arrange them one way, atoms make up the air we breathe; arranged another way, they make up the family dog. If you could rearrange the atoms in a lump of coal, you'd have a diamond. If you could rearrange the atoms in a can of Spam, you'd have your next-door neighbor.

In *Outpost*, you have the opportunity to develop molecular nanotechnology through research on many different subjects, reflecting the multidisciplinary approach that will be necessary to achieve this capability. Nanotechnology is defined as the thorough, inexpensive control of the structure of matter based on molecule-by-molecule control of products; the products and processes of molecular manufacturing.

This chapter describes the concept of nanotechnology. It will explain why nanotechnology is such an important research goal in *Outpost*, assuring the survival of your civilization and revolutionizing the industry of your colony. Along with terraforming, nanotechnology represents the highest level of technological development that your civilization can reach.

Nano-what?

Our current level of manufacturing technology requires several crude steps to process some form of raw material into a finished product that will eventually fail due to age or wear. To build a car, industry uses a top-down approach to reduce a mountain into rubble, which is processed into iron, which is transformed into steel, which is cut and molded to become a Mercedes. A natural thing is pounded with all kinds of crude human technology and labor to become a new kind of tool for humans. What Eric Drexler, the world's leading expert on nanotechnology, is suggesting is that industry should work with matter from a bottom-up approach, manipulating molecules with tiny machines to build a Mercedes that will never wear out.

A form of nanotechnology already exists in natural processes. A tree doesn't have to do anything as crude as cutting and molding wood chips to make leaves. It starts by gathering solar energy through the photosynthetic reaction center of a chloroplast, the molecular biological equivalent of an electronic device. The solar energy drives molecular machines within the tree that perform precise functions with their moving parts, processing carbon dioxide and water into molecular building blocks. These building blocks are handled by molecular assemblers according to the needs of the tree, sprouting leaves according to the built-in blueprint of leaves that have always been constructed by the ancestors of that tree. As each leaf is assembled, more solar collectors are built within its cell walls to help support the new load of nutrients required to maintain that new leaf, as well as the machinery in the rest of the tree. This leaf-building system is quiet and efficient, producing no toxic wastes as a by-product. At first glance, the tree appears to be operating a low-technology operation, but its growth process is far more sophisticated than a car manufacturing facility, so perhaps it should be called high technology.

Unlike biotechnology, which alters organisms to produce variations considered more useful to humans, molecular manufacturing builds intricate products from basic molecules. Imagine a car assembly plant full of huge mechanical machines, then shrink it down until it's smaller than bacteria—that's the scale of difference we're talking about with nanotechnology.

In 1959, Richard Feynman, who would later win the Nobel Prize in physics, gave a speech at the annual meeting of the American Physical Society. His visionary talk, "There's Plenty of Room at the Bottom," described a mechanical approach to tiny machines. A large machine would build a smaller machine, which would build a smaller machine, and so on until machines were being built atom by atom. He said this process would not defy any laws of physics, but it had not been done so far because humans are too big. Feynman speculated that chemistry would be the answer, placing atoms together to form substances.

Twenty years later, when Feynman tried to describe his idea of microscopic machines to a group that didn't understand the concept, he said: "It has to do with the question of how small you can make machines. [Pinching an invisible tiny machine between thumb and forefinger.] You know, very small *machines*. I am talking about very—tiny—machines. Okay?"

To get a better idea of scale, an atom is about 1/10,000 the size of a bacterium, which is about 1/10,000 the size of a mosquito. If an atom were the size of a pearl, a complex molecule would be about the size of a baseball. Microcircuits have parts measured in micrometers, millionths of a meter, whereas molecules are measured in nanometers, billionths of a meter, which are a thousand times smaller. So far, the smallest microminiaturized component is about

50 nanometers, which is the width of 500 hydrogen atoms side by side. That's small, but not small enough.

Molecular Manipulation for the Ultimate Control Freak

Because human hands are about 10 million times too large, scientists have no direct and convenient way to control the placement of molecules. Molecular structures, known as *polymers*, are now made through indirect methods such as mixing and heating, which take advantage of molecular bonding tendencies. Genetic engineers have improved on this process by programming bacteria to produce useful proteins such as human growth hormone and enzymes used to make cheese. However, because protein machines stop working when they're dried, frozen, or heated, they aren't perfect for engineering purposes.

The idea of nanotechnology uses what looks like an industrial robot arm on a microscopic scale. This programmable molecular assembler, using molecular-scale tools, can grasp a large molecule, the workpiece, and bond a smaller molecule to it. This produces a larger structure while maintaining control over the arrangement of its atoms. The same way that regular tools can build a car from parts, molecular tools can bond molecules together to make tiny gears, motors, levers, springs, and casings, then assemble them to make complex machines. Each piece could be built of carbon atoms arranged into flexible diamond fibers over 50 times as strong as the same weight of aluminum.

Assemblers and other machines in molecular manufacturing systems will be able to bond atoms together in any stable arrangement, allowing the construction of almost anything, if given the correct raw materials.

Computer circuits will also continue to shrink in size and cost, limited only by the uncertain nature of the quantum behavior of electrons. As is true now, electronic circuits speed up as they get smaller, but Eric Drexler has also proposed mechanical computers, with components a few atoms wide, that could fit in a box a micron wide, about the size of a bacterium, with a billion bytes of storage. This would be billions of times more compact than the microelectronics in your home computer. Although the mechanical signals in these computers would travel about 100,000 times slower than electrical signals in today's computers, they would have to move only 1/1,000,000 as far, which means they would work faster than the best machines today. When these molecular computers are refined enough to move from the mechanical stage to the electronic stage, they will be hundreds of thousands of times faster than electronic microcomputers.

Nanocomputers will direct the actions of molecular assemblers, directing the placement of vast numbers of atoms to build just about anything you want—structures, robots, spacecraft, or microbots such as the one shown in Figure 25-2. The all-encompassing result of discovering nanotechnology in *Outpost* is simple, but it will make a big difference in how you play the rest of the game.

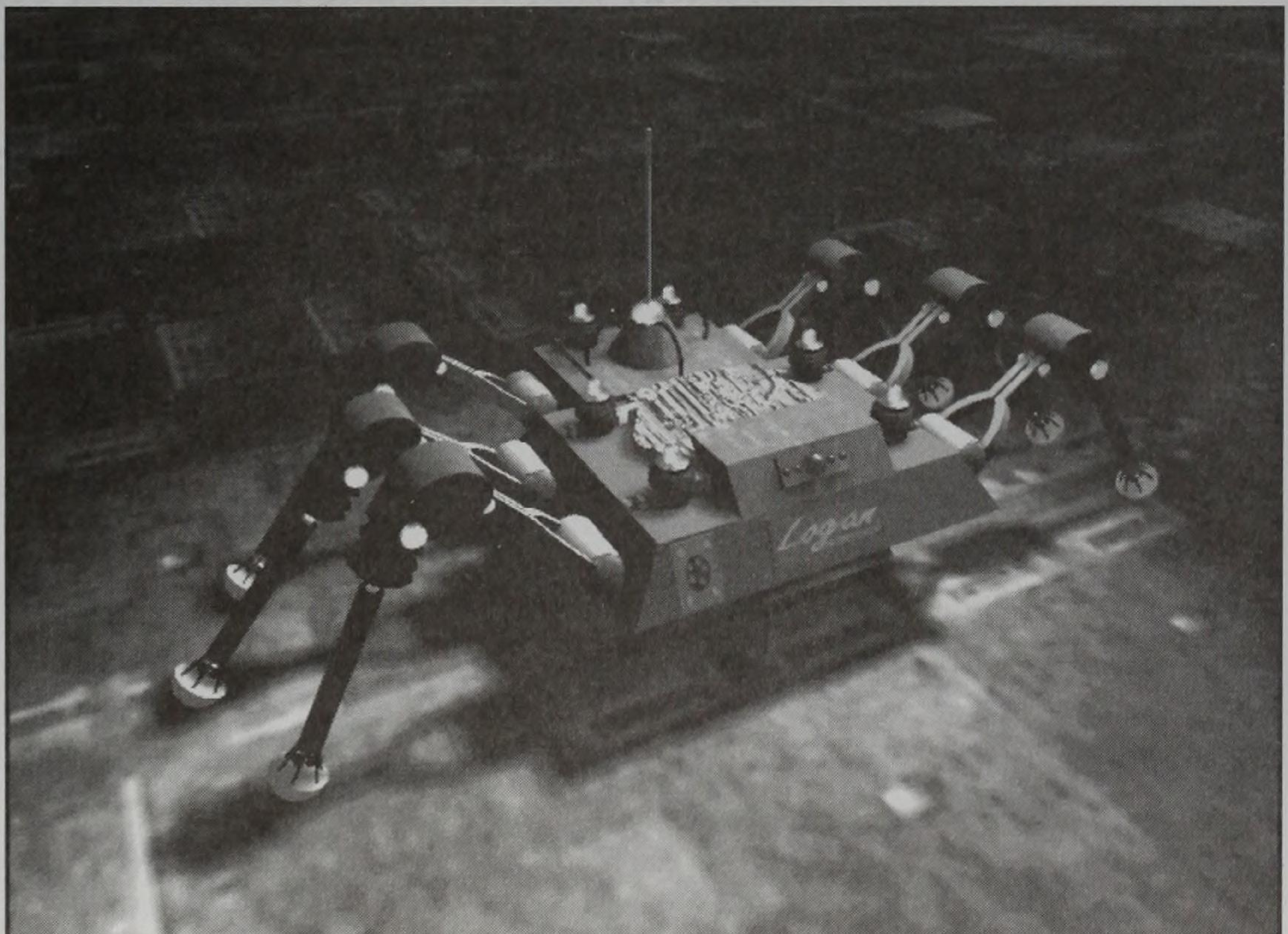
The Effect of Nanotechnology on Your Colony

The discovery of nanotechnology is an important event in the life of an *Outpost* commander. Resource limitations will no longer be a problem whenever you have a nanotechnology facility, as shown in Figure 25-1, operating in your colony. This is an important distinction, because each colony operates independently when it comes to resource utilization. You must build a nanotechnology facility in each colony to remove your resource limitations in that colony.

Power must still be provided to operate the nanotechnology facility, but it essentially has the ability to use plain old dirt, or anything else, in place of processed resources for its operation. The immediate effect of operating these facilities is that you are no

Figure 25-2

The Effect of Nanotechnology on Your Colony



longer oriented toward the basic means of survival on your planet. Your mines and ore transportation systems are no longer limiting factors on the growth of your colonies. Medical nanotechnology will improve the health of your population to keep them living and working longer. The terraforming of appropriate planets will become possible when combined with other research. Food production will improve. Command of your colony will be simplified. Bald people will grow new hair. The common cold will disappear. The…well, you get the idea. Nanotechnology is a nice thing to have.

When your scientists discover nanotechnology, and you implement molecular manufacturing, you will have assured the survival of your civilization. Your absolute control over matter will revolutionize the industry of your colony. Having arrived at the highest level of technological development that your civilization can reach, you will have demonstrated your excellent grasp of leadership to the population of your planet. This is a good thing. The world needs more people like you.

Confident of your success now that you've gotten this far in the book, I know you've probably been wondering when I'm going to get around to describing the silly things you can do while playing *Outpost*. You've had enough science and strategy, now you just want to blow something up or tweak the simulation in an unexpected way that will make pulsed laser beams shoot out of your monitor. Am I right? If I am, read the next chapter to learn all about stupid *Outpost* tricks that will amaze your friends and stun your enemies. If I'm wrong, I'm wrong—so shoot me.

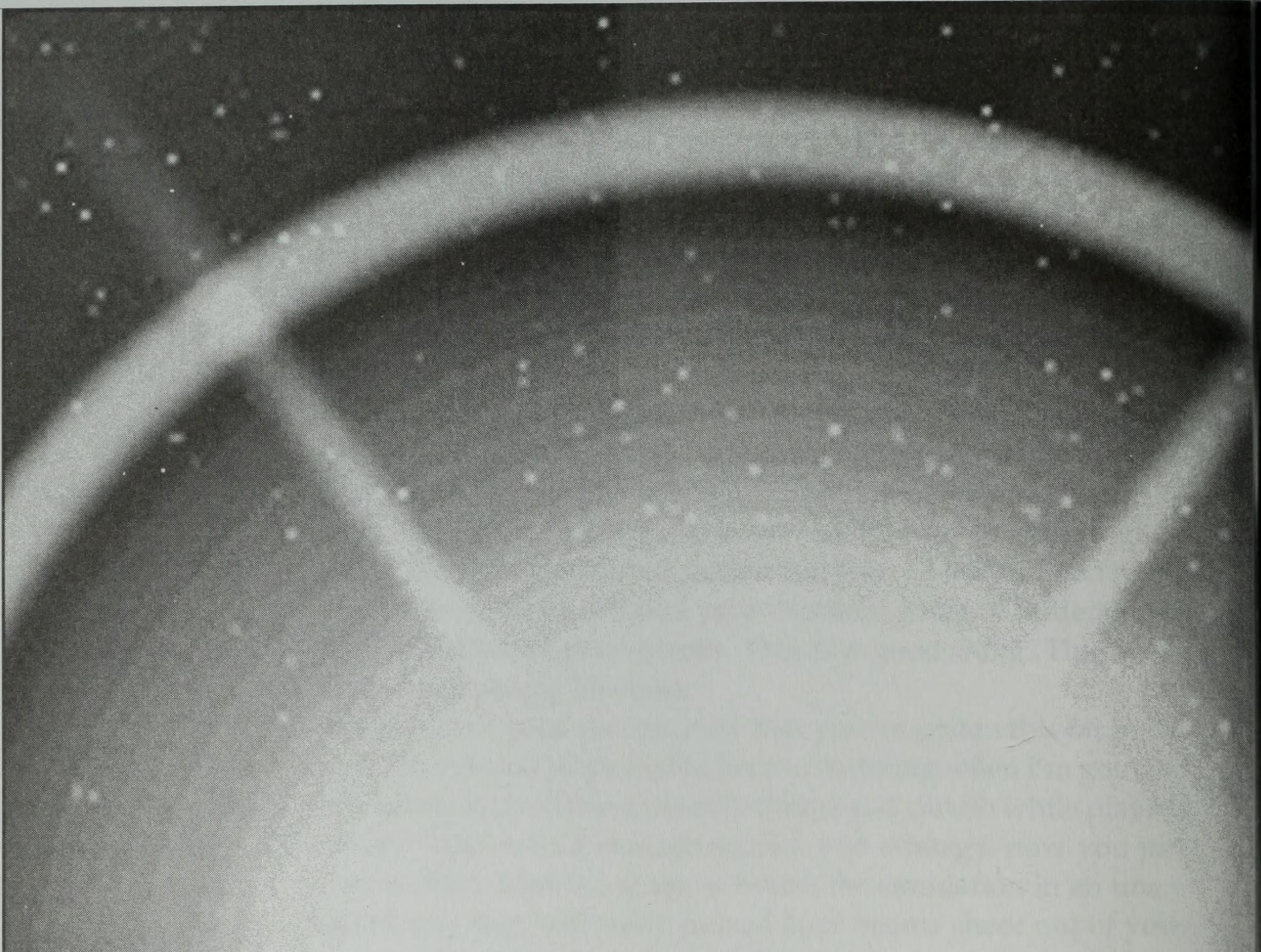
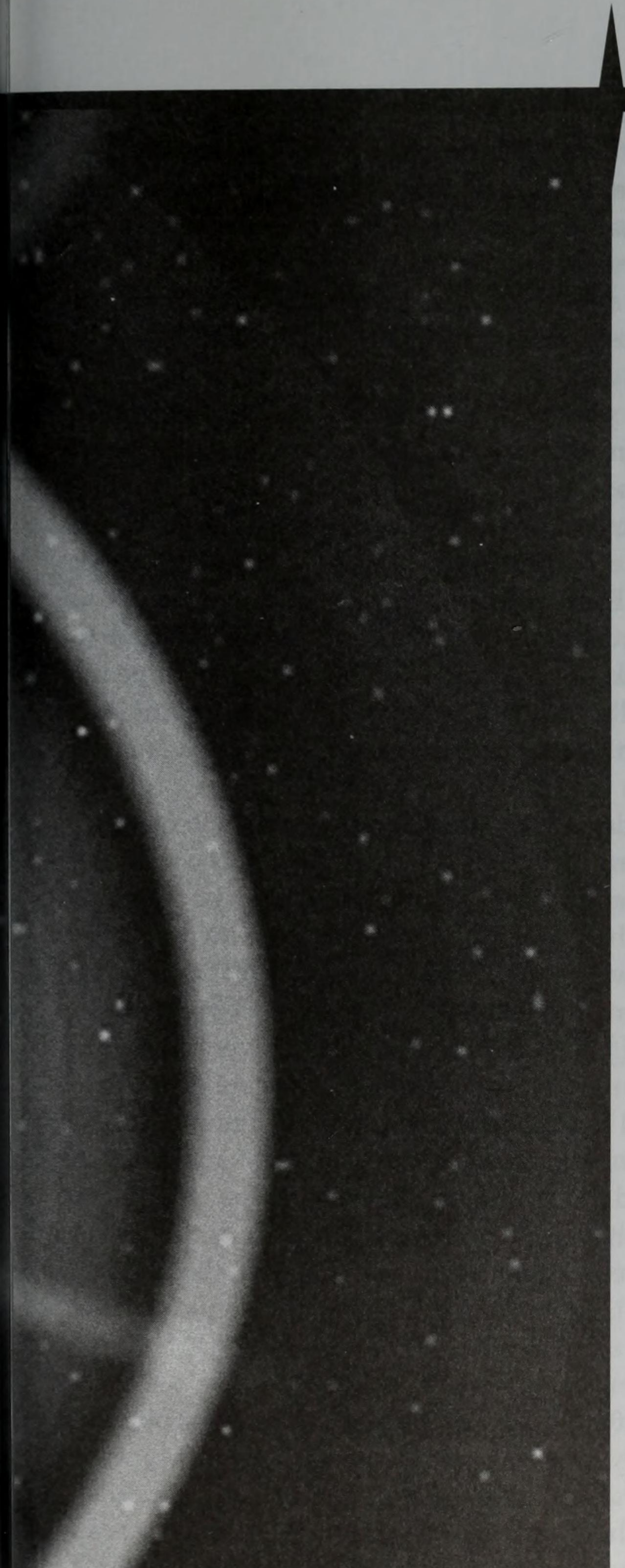


Figure 26-1 Your planet explodes when you quit without saving.



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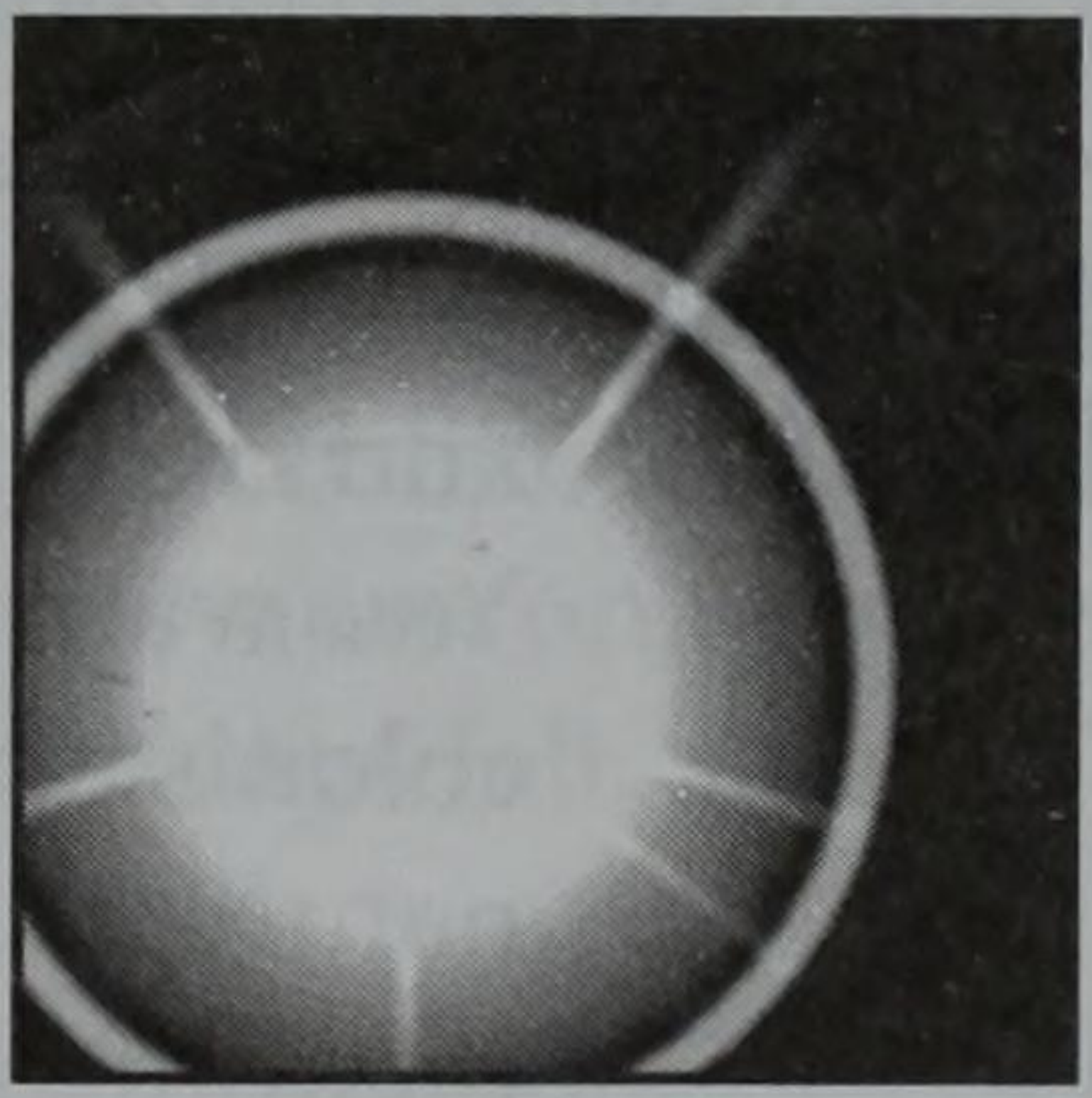


Stupid *Outpost* Tricks

I don't want to achieve immortality through my work, I want to achieve it through not dying.

Woody Allen

There are a few special keystrokes in *Outpost* that were thrown in for testing purposes, then left in for amusement purposes. The time has come to reveal these wondrous features to the world at large, allowing the player to wield even greater powers than before. Because some of these features are major cheating methods, I'm warning you again to avert your eyes before something horrible happens.

The Armageddon Button

Things are going well, your people are happy, factory production is high, research progress is amazing, babies are being born left and right, the colony is safe, and you want to stir up some trouble. You want to create some conflict between the forces of good, the colonists, and evil, the environment. You want to spit in the eye of nature as if you were Ernest Hemingway. What do you do? You push the Armageddon Button, Ctrl-F10, and force a disaster to strike your colony. Pick any disaster from the menu that appears, then your colonists will think they're living in hell. Why wait for a random planetary event to occur when you can make one yourself?

Mass Driver Misfire

Okay, this one was added for our own amusement. Remember that rebel colony that ran off with half of the stuff you packed on the starship? Remember how they disappeared when you arrived at the planet, saying they were going to form their own colony? Remember how you wanted to smash their faces off? Well, now you can do it and blame the whole disaster on newfangled technology. Pressing Ctrl-F9 will cause the Mass Driver to misfire, assuming you've built one. The misfired load, accelerated to a tremendous velocity, will travel just a few feet off the ground until it passes over the horizon and slams into the rebel colony, destroying both the colony and its inhabitants. This means you won't have a trading partner any more, or a possible colony acquisition if you could have made the rebels defect to your colony, but the destruction of their colony is strangely satisfying for some people, including me.

A Button for Manic Depressives

You say you're tired of all the mood swings among your population? One moment they love you, and the next moment they want to make you take a walk outside without a spacesuit? You wish you could make the whole mob take a Valium? Well, now you can force the whole crowd to take a digital Valium by pressing Ctrl-F12. This gives you the option of forcing morale to the maximum value, which means they're all ecstatically happy, or to the minimum value, which means they're all so depressed that they're planning to pack up and leave town to get away from you. Morale will start rising or dropping again on the next turn, but it should have the desired effect for several turns before it wears off.

A Free Lunch

Are your resource requirements getting you down? Are you feeling limited by what your mines are able to produce? Are you wishing you could just discover nanotechnology and ignore resource requirements from now on? Pressing Ctrl-F11 allows you to have an endless supply of resources, much like the effect of having discovered nanotechnology. From now on, you will have no limitations, which is how you've always felt, right?

Ego Massage

You've put over 300 hours into playing variations of *Outpost* scenarios. Your mate has left you, your friends can't remember your name, and your dog won't lick you any more. Staring at your computer screen at 2:00 in the morning, you're starting to think you'd like a little positive reinforcement for a change, so you reach for Ctrl-F8. Your ears fill with the sounds of a crowd applauding and cheering your efforts. All is right with the world. Now you can get back to the game without feeling guilty.

Destroyer of Worlds

This isn't what I would call a hidden feature, but it may be something you haven't tried. If you quit an *Outpost* game without saving, and you have the CD-ROM version, you'll see a brief animation of your planet exploding. If you have the floppy disk version, you'll see a still graphic of the same event. There's no scientific basis for your planet to explode, but it feels good sometimes. Don't let it worry you.

This chapter has filled your head with a load of useless keyboard commands that have no practical value, other than your own amusement.

The next chapter is a blatant commercial for new *Outpost* products that will be slamming into your software dealer's shelves in the near future, if I have anything to say about it.

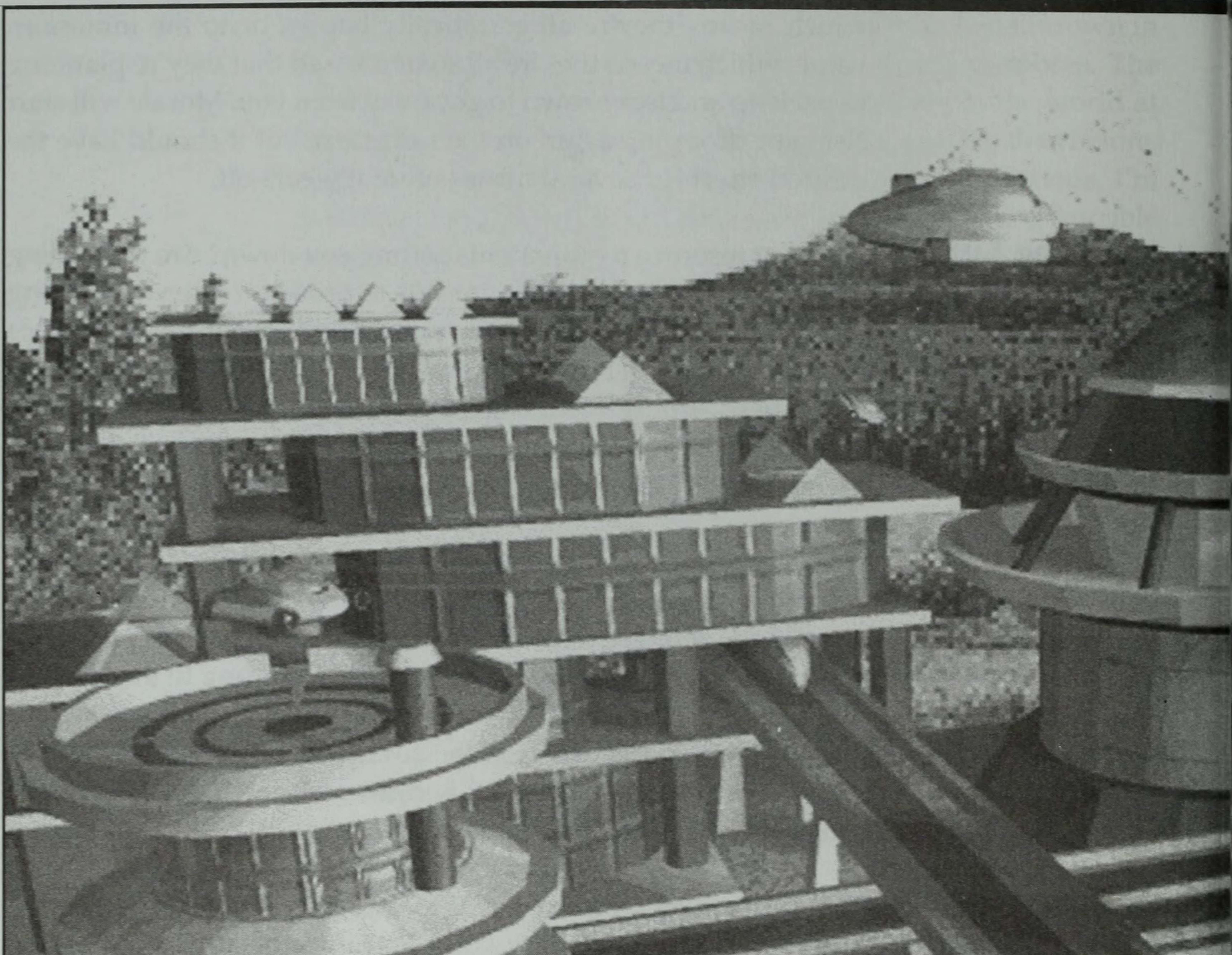
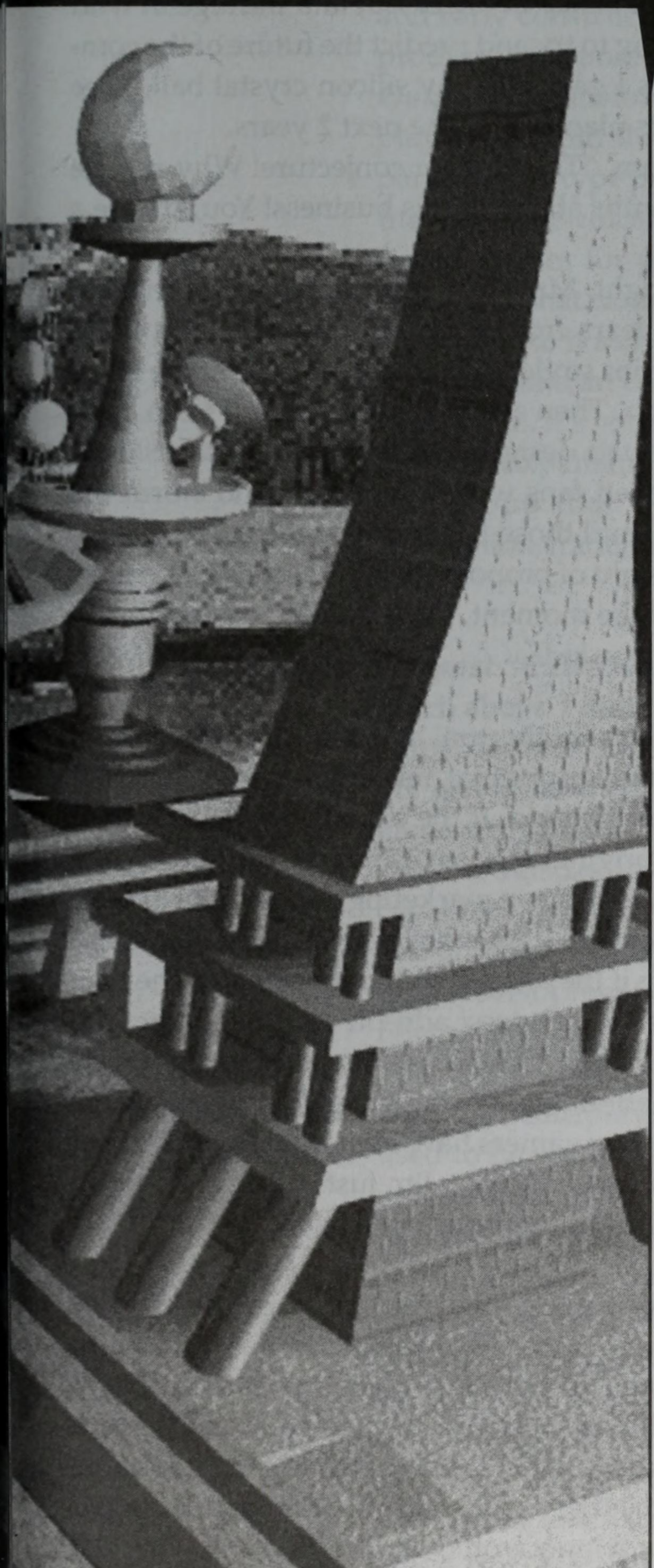


Figure 27-1 Early rendering of an advanced colony



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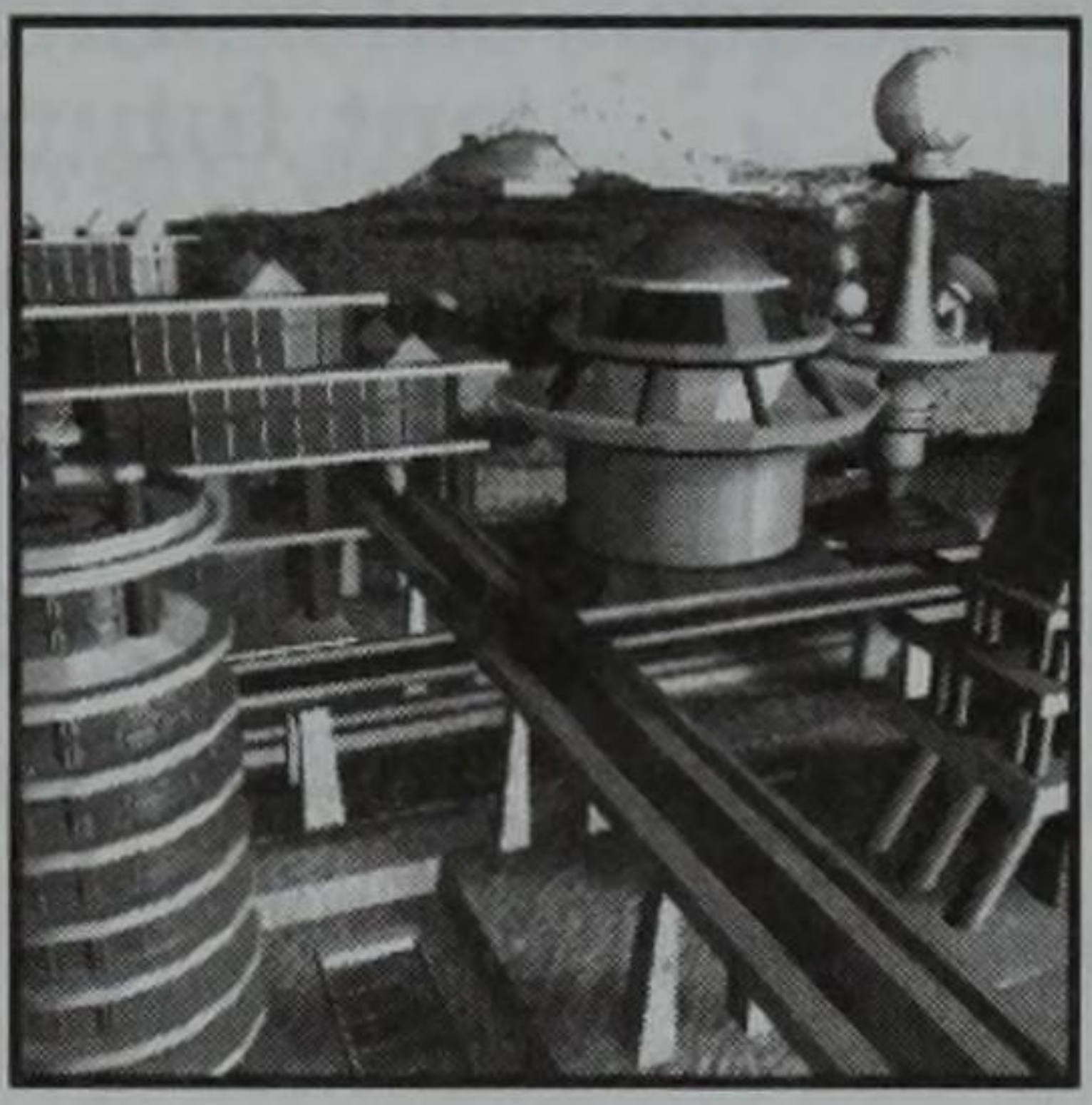


Outpost and the Future

Never put off till tomorrow what you can do the day after tomorrow.

Mark Twain

This is the chapter where I stick my neck out and indulge in wild speculation. Yes, I'm going to try and predict the future of the computer game industry. As I gaze into my silicon crystal ball, I see several *Outpost* products planned for the next 2 years.

"Two years," you scream. "That's sheer conjecture! Why, no one can see more than 6 months ahead in this business! You, sir, are a rambling madman!"

Well, perhaps you're right. Maybe an anthropologist of the distant future, let's say 4 years from now, will look back on these predictions with a superior smile and remark on how naive I was to go so far out on a limb. Then again, maybe not. All I can do is talk about planned products designed to expand the *Outpost* universe and hope that crazed fans will write letters and storm the walls of Sierra On-Line until those products are released.

Shield your eyes if the sight of proposed product schedules makes your blood run cold. At the moment, these games and expansion modules exist only in my mind.

Expansions, Conversions, and Sequels, Oh My!

My lead programmer, Dan Brotherton, and I think we're darned clever about having created an original, reusable game system that can be customized and expanded. If the expansion modules had been included with the original release of *Outpost*, the list price of the game would have made grown marketing people faint at their desks. However, we wanted a game that people could spend the rest of their lives playing if they had no other interests, so the idea of releasing smaller, cheaper, *Outpost* add-on modules came into being. This way, we could continue to use the latest technologies to create the best simulation game experiences (simulated game experiences?) that computer gamers have ever seen. Now, I'm not saying that sim gamers have no lives. I'm just making the point that sim gamers know what's important in life.

Expanding to Fill the Available Space

***Outpost* Expansion Module 1** Under the working title of "Planetpack," the primary purpose of this add-on would be to increase the number of star systems and planet types available to the Outpost fanatic. This is for those who have already spent thousands of hours traveling to the 30 star systems in the first game and colonizing the wide variety of planets. In addition, packaged colonies with existing problems would be included, allowing the player to jump right in and manage the situation without the setup and early construction period required in the original game. This product is proposed for fall, 1994.

***Outpost* Expansion Module 2** This terrain editor would allow players to build their own customized planets from a library of parts. Venus-type planets aren't tough enough for you? Make one that has more volcanic activity. Our asteroids have too much room and resources for you? Make one that's no bigger than a swimming pool that can produce only mined life support materials. Go ahead, make it as hostile as you want and see how long you can last. Or make an easy planet that you can live on in your retirement years. It's your choice. This product is proposed for fall, 1994.

***Outpost* Expansion Module 3** This module is for the science fiction group that wants to interact with alien races through exploration, trade, and/or specialized combat. Proposed for spring, 1995.

Big Sequel

***Outpost* "CyberWar" Sequel** This is a secret project I can't say much about. I didn't want to turn this into a direct combat sort of game, because there are already enough of those. Using the terribly clever technology we have at our command, this full-sized game will create a new form of combat based in the *Outpost* universe. It's also possible that this sequel will add full interplanetary capability to allow multiple colony operations on a larger scale. The strategic challenge of the simulation at this level requires a long development time, so we have proposed this project for release in spring, 1995.

Multiplayer Versions

***Outpost* Multiplayer for INN** The ImagiNation Network (INN) used to be part of the Sierra family of companies, but they went independent a year ago. INN is probably the fastest growing online service in the country devoted exclusively to games. By the end of 1994, we want to have a multiplayer version of *Outpost* running on INN. In place of the rebel colony run by the game's artificial intelligence, you would have real human opponents fighting for survival on the same planet. Because you can communicate with the other players, you can gang up on colonies you don't like by forming an economic barricade to bring them to their knees. Learn the subtle art of diplomacy by lying to one player while you make bargains with another, then stab them both in the back when the opportunity arises. On the other hand, you can form vast alliances with interlocking trade networks between colonies that will rival the economic strength of the modern-day superpowers on Earth. The possibilities are almost endless.

***Outpost* "CyberWar" Multiplayer for INN** Using the awesome capabilities of the INN network to their fullest, this game would create a new level of reality for multiplayer interaction. Whereas the solitaire version of the game for the average gamer would generate a whole new environment in their computer, this network version would leap from the fictional confines of the game to become part of the real world with human opponents. Proposed for fall, 1995.

Macintosh Conversion

***Outpost* Macintosh** For the Mac users who have accosted me in the street and threatened my life unless we give them a Mac version of the game, we'd like to have this available by the end of 1994.

I have a few more ideas in mind, but I just wanted to give you a taste of what we have planned for the near future. Remember that these games do not exist as I'm writing this. Their development will depend on the sales of the first game, which has already garnered a "Best of Show" award from the winter 1994 Consumer Electronics Show. With any luck, you'll see these products on computer store shelves in the near future.

Okay, that's the end of the commercial. Now, let's look at the art in the game. You've been seeing black-and-white examples of the *Outpost* art all through this book. No other simulation game has produced this quantity or quality of high-resolution, three-dimensional rendered artwork. If you're curious about how it was done, the secrets of the computer graphics will be revealed in the next chapter.

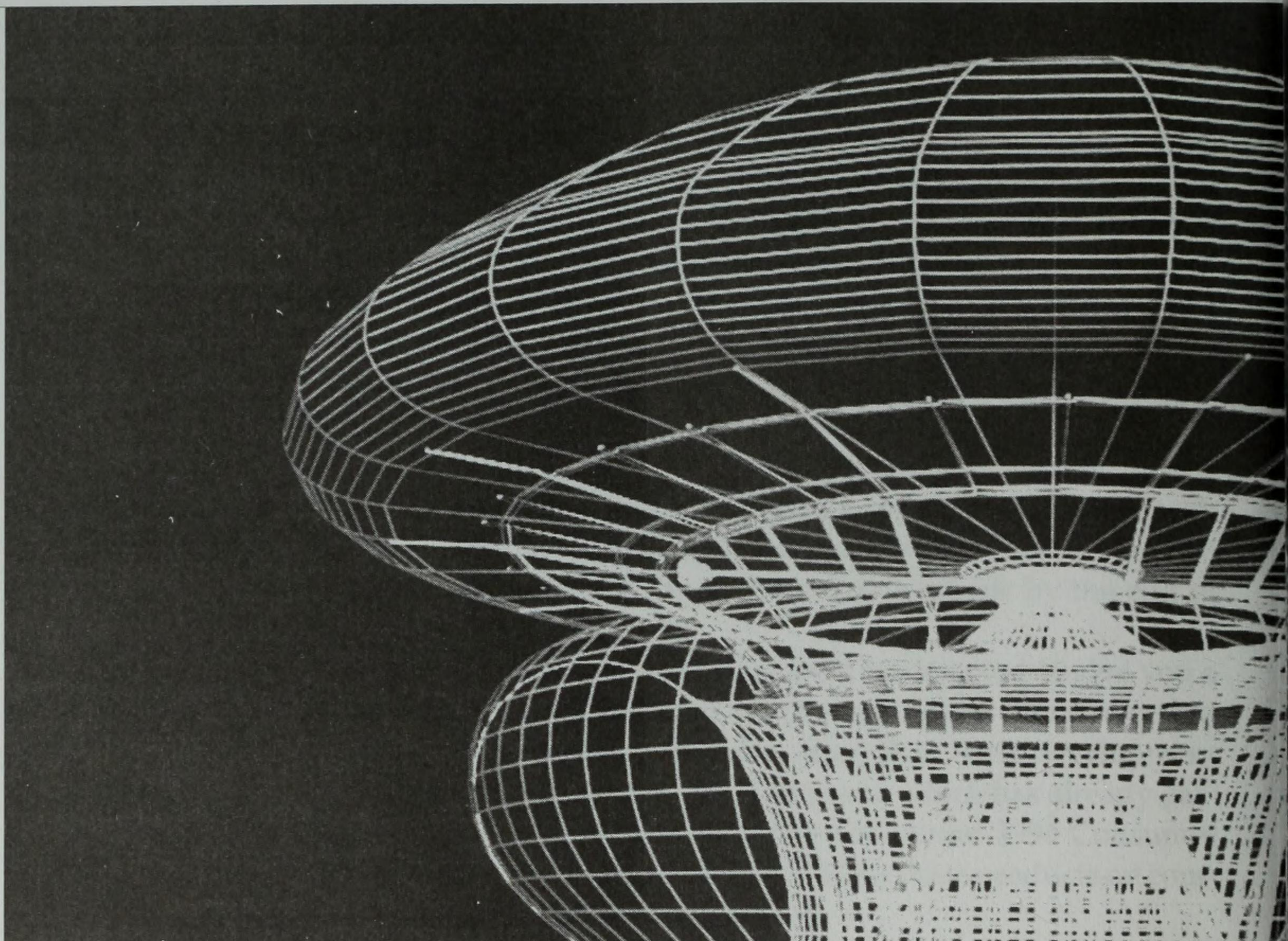
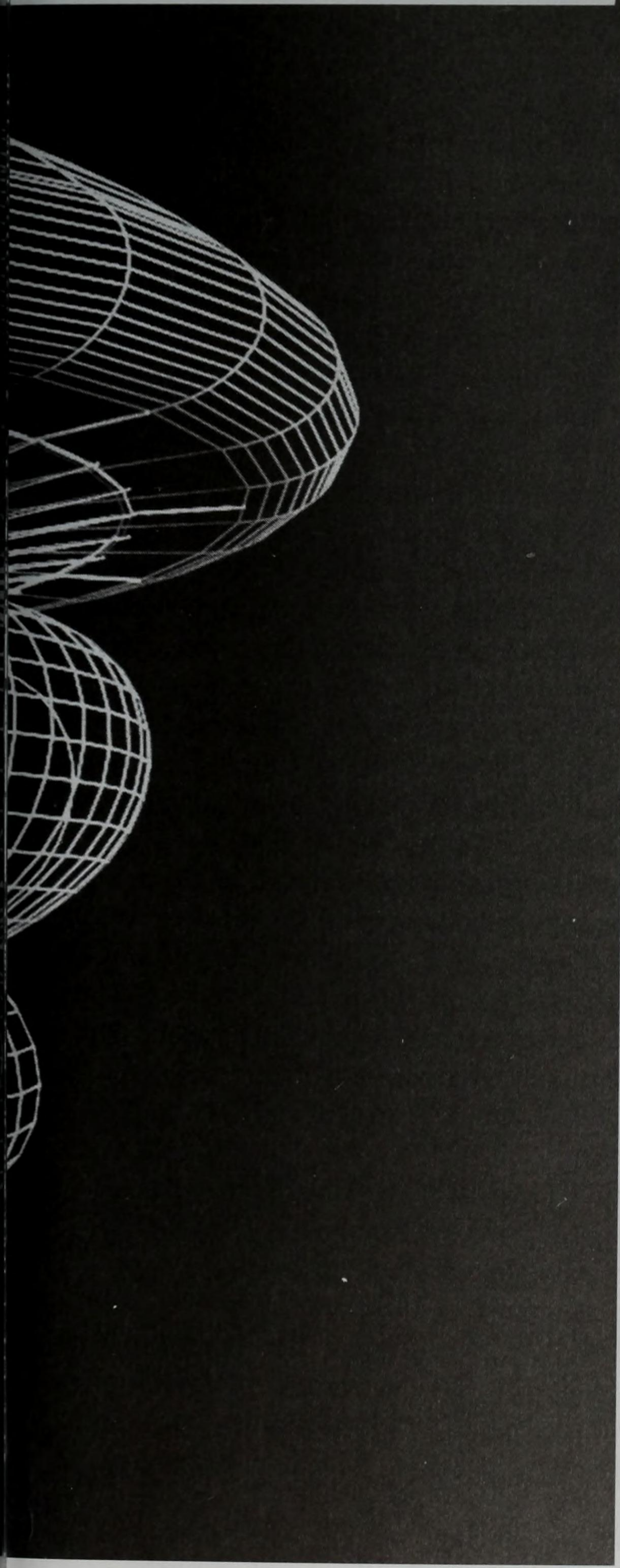


Figure 28-1 Wireframe model of the starship



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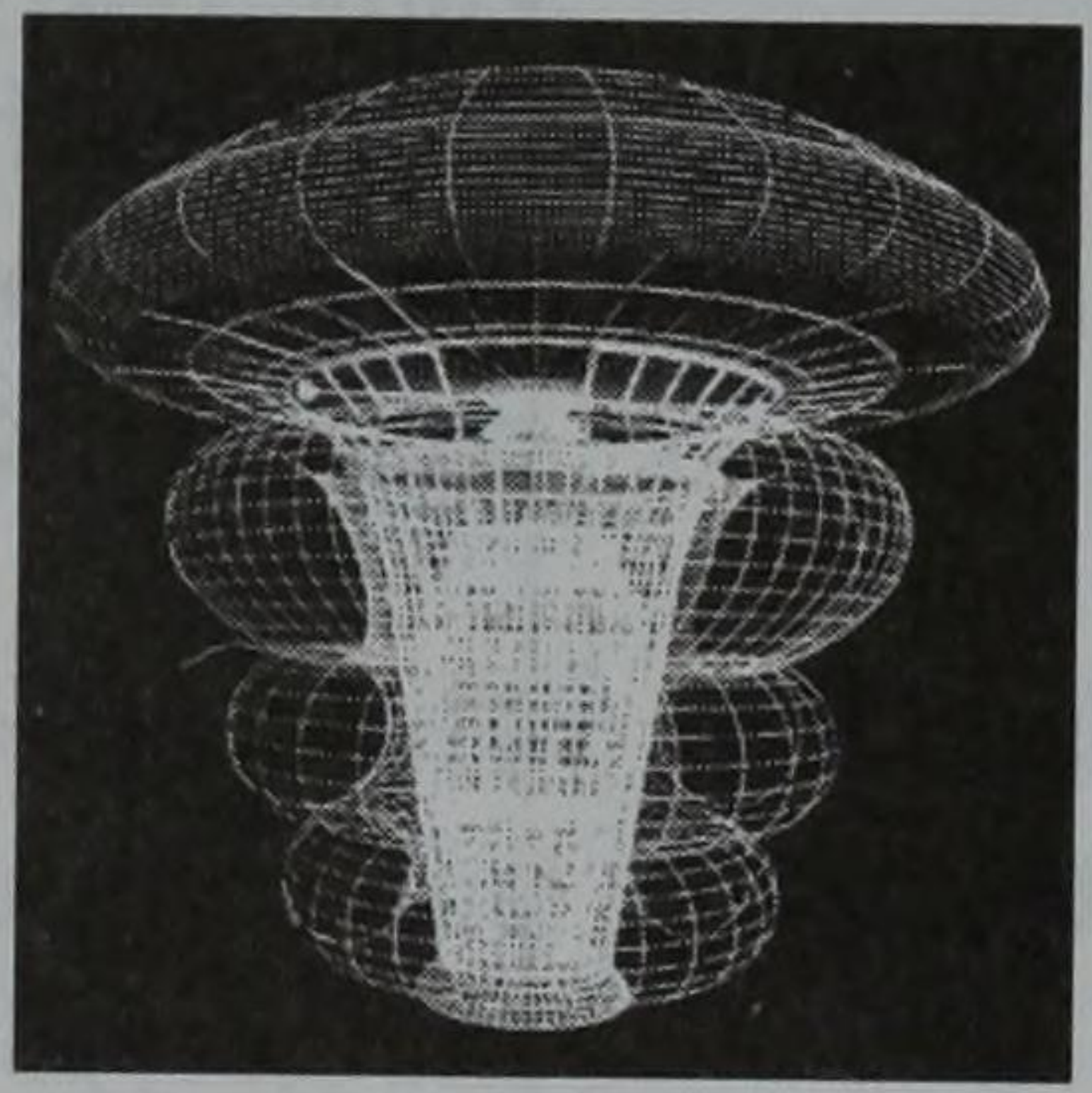


The Art of 3-D Rendering

A man paints with his brains and not with his hands.

Michelangelo

For the moment, we have an advantage with the art in *Outpost*. Up to this point, no other strategy simulation game has used three-dimensional (3-D) rendered graphics for the entire game. Our animated sequences were also done this way, with the same software tools used by television and film production companies. Computer graphics technology is rapidly leaping forward into the future, bringing computer games closer to reality. The art in the game had to look believable, and you can see examples of these graphics throughout this book. To accomplish this level of quality, we had to use sophisticated new art tools. For a realistic space colonization game, there really wasn't any other choice.

Production Sketches

The art for *Outpost* took over a year to develop. Even on our high-end computers, the time required to process detailed 3-D rendered imagery is enormous. The longest of the animation sequences took about 7 days to render on a computer with a fast processor. A typical animation sequence would be set up during the day and left to render overnight. Then, if a mistake was made, the same sequence would have to be corrected, set up again, and left to render over the next night. With the work split between two artists, Jon "Vampire" Bock and Rich "The Cannibal" Powell, *Outpost* became the best looking product ever to come out of Sierra On-Line.

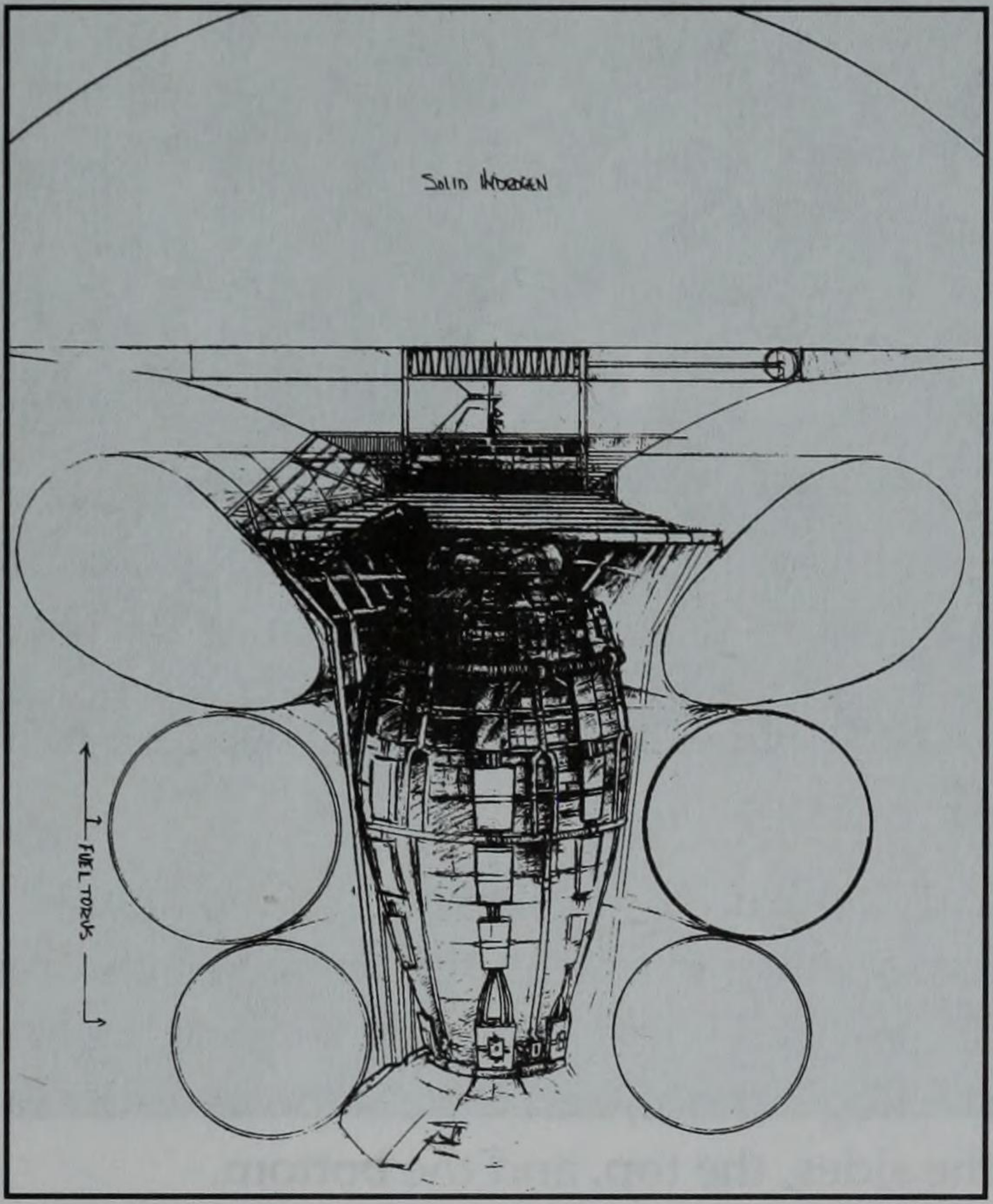
Figure 28-2 shows one of the production sketches of the colonization starship. Our starship consultant from the Jet Propulsion Laboratory, Greg Tomko-Pavia, spent a considerable amount of time working with the artists to ensure the accuracy of the design. In fact, so much time was spent on the design of the starship that several people outside the team were convinced we were actually going to build the thing. They were wrong, of course. We didn't have time. Maybe next year.

Figure 28-3 is a production sketch of the Seed Factory by Jon Bock. The animated sequence of the Seed Factory landing required several days to model, choreograph, light, animate, and render.

Once Rich Powell's starship sketch was approved, the "wireframe" model in Figure 28-1 was built on the computer with Autodesk *3-D Studio*, "texture maps" were applied to the wireframe to give the hull the proper appearance, lighting angles were specified, and the final rendering began. One of the finished images is shown in Figure 28-4.

Figure 28-2

Production sketch of the colonization starship


SOLID HYDROGEN
FUEL TORUS

Wireframe Models

The wireframe model is the first step in building this type of detailed image on a computer. A wireframe model of the Seed Factory is shown in Figure 28-5. The wireframe defines the basic shape of the image, just as the internal framing of a house determines its final appearance. Many shapes are predefined in the software, saving time when it comes to forming the wireframe.

Figure 28-3

Seed Factory sketch

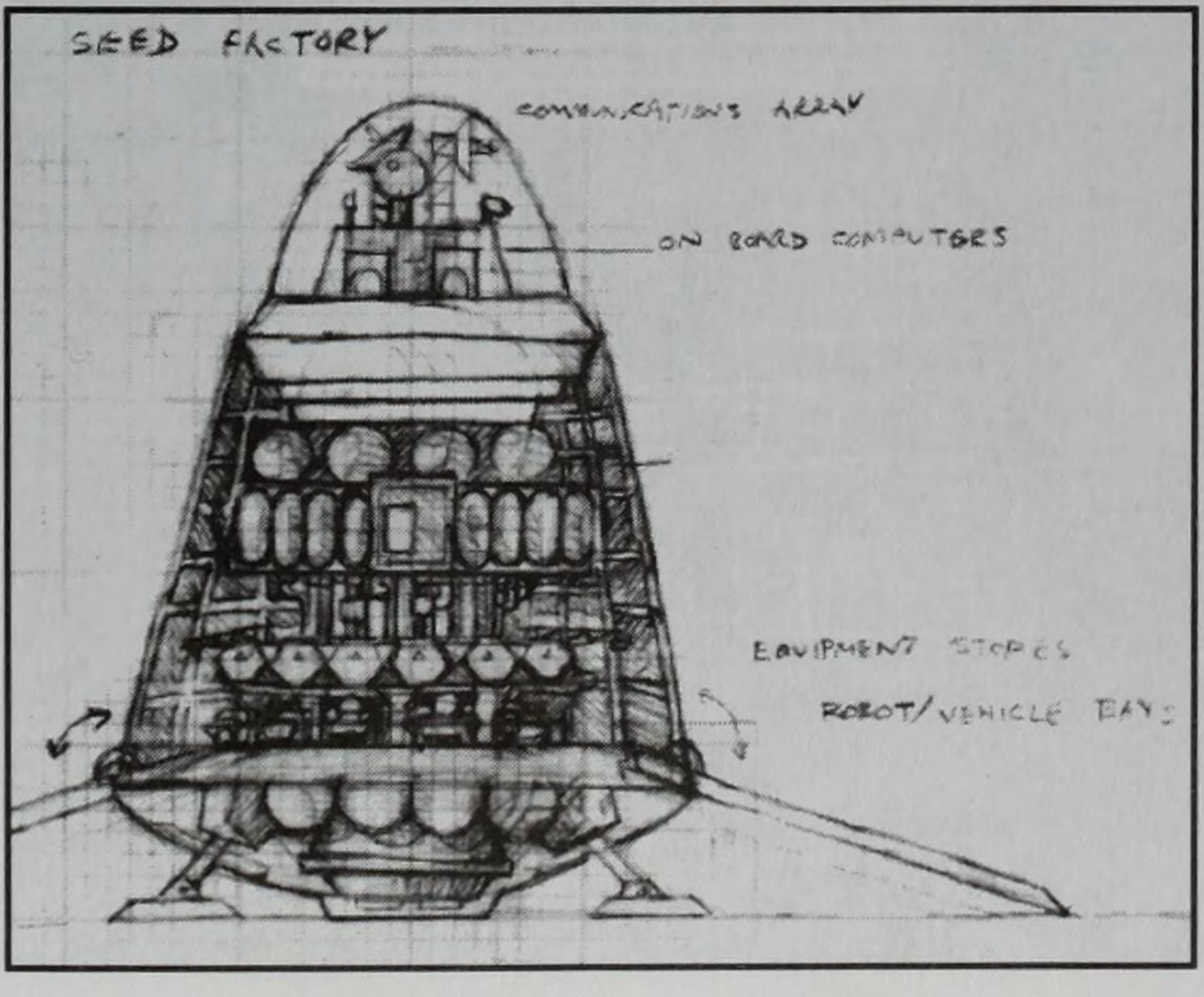
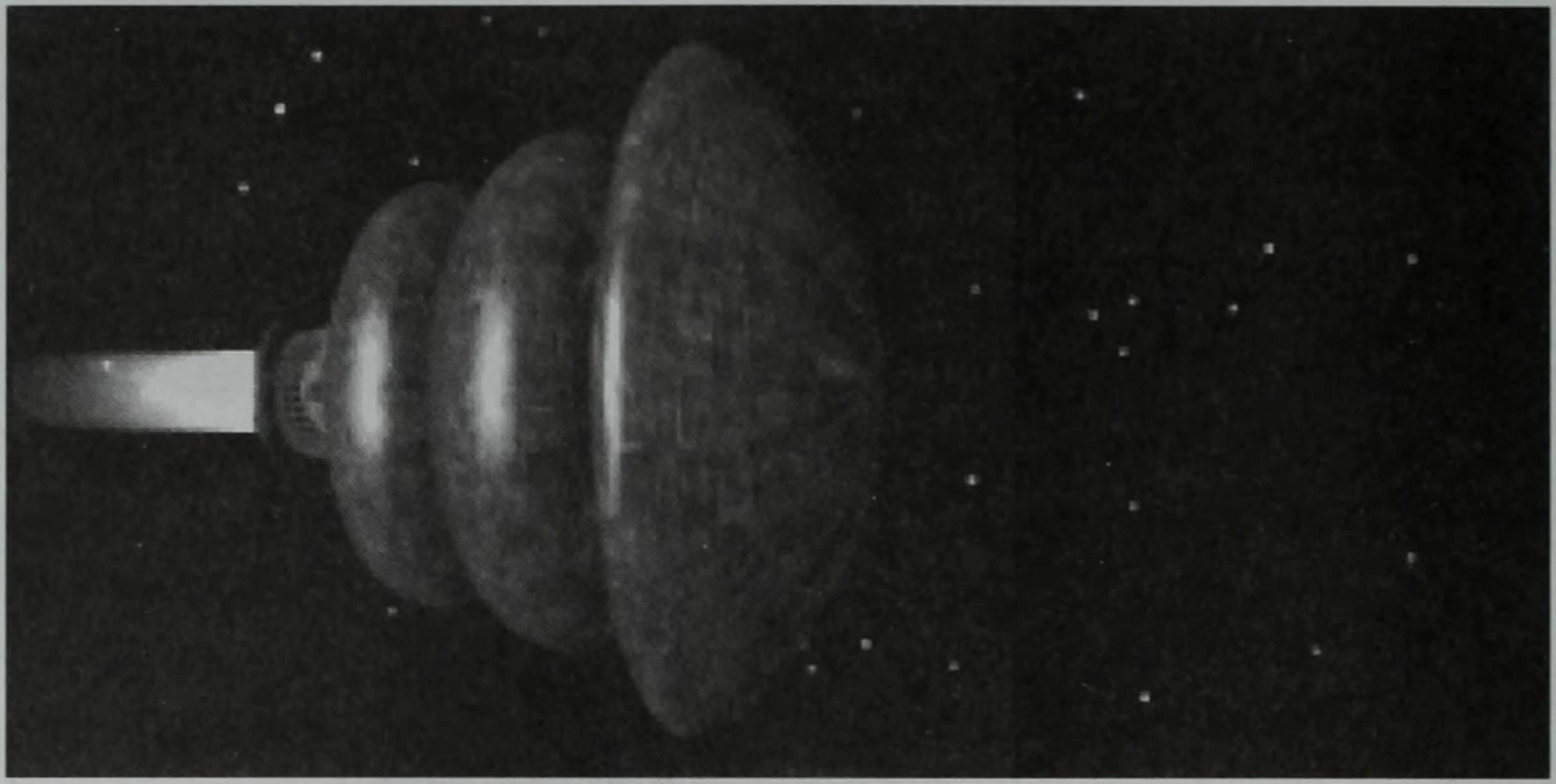

SEED FACTORY
COMMUNICATIONS ARRAY
ON BOARD COMPUTERS
EQUIPMENT STORES
ROBOT/VEHICLE BAYS

Figure 28-4

Finished rendering of the colonization starship



While the image is formed in one dimension, the computer mathematically interpolates the shape to show how it appears from other angles. This way, the artist can create the front surface, or any other starting surface, and the computer finishes the job from the back, the sides, the top, and the bottom.

3-D Rendering

Once the wireframe model is complete, different kinds of mapping can be applied. In general, reflection maps are used for shiny

Figure 28-5

Seed Factory wireframe prior to rendering

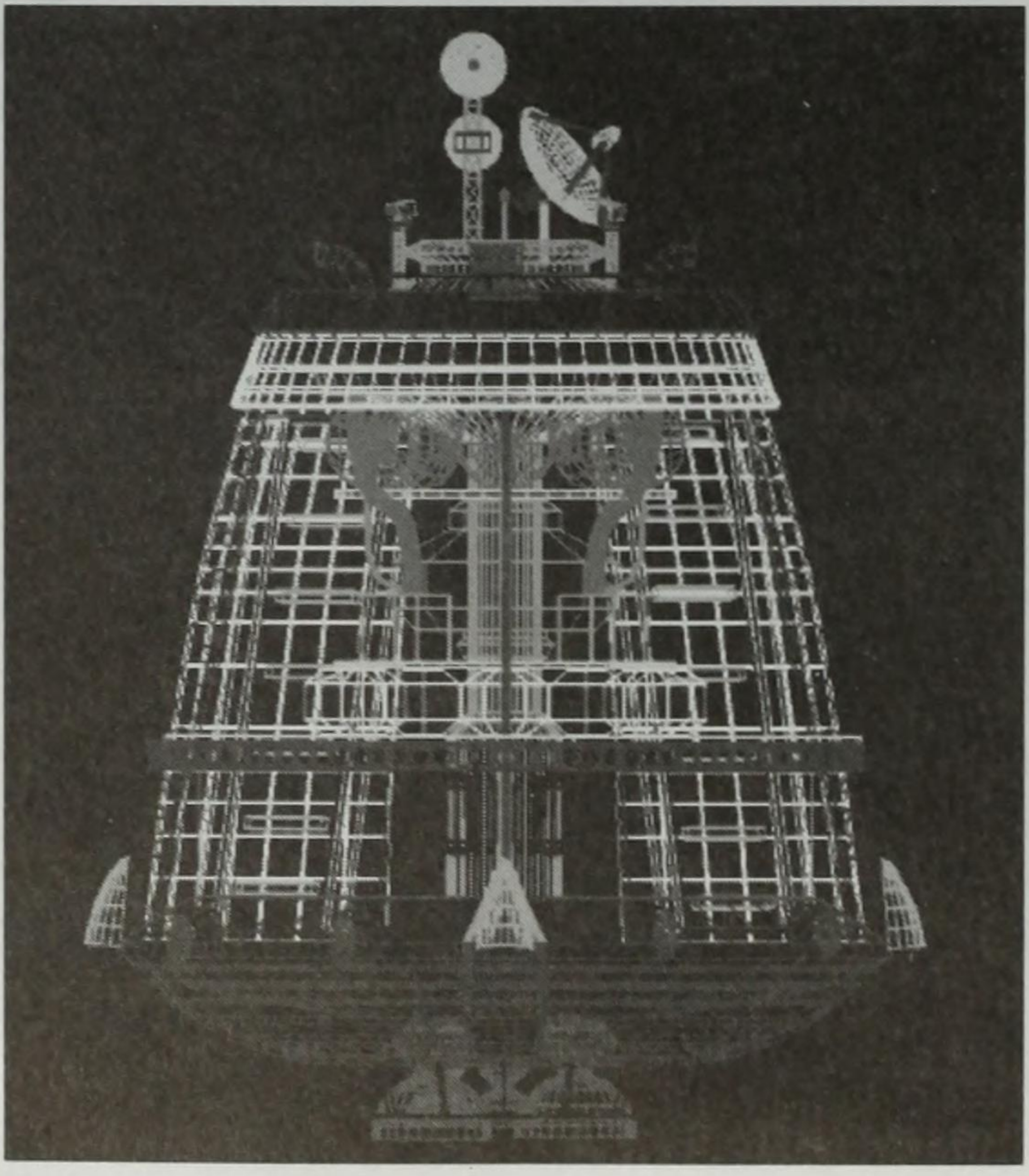
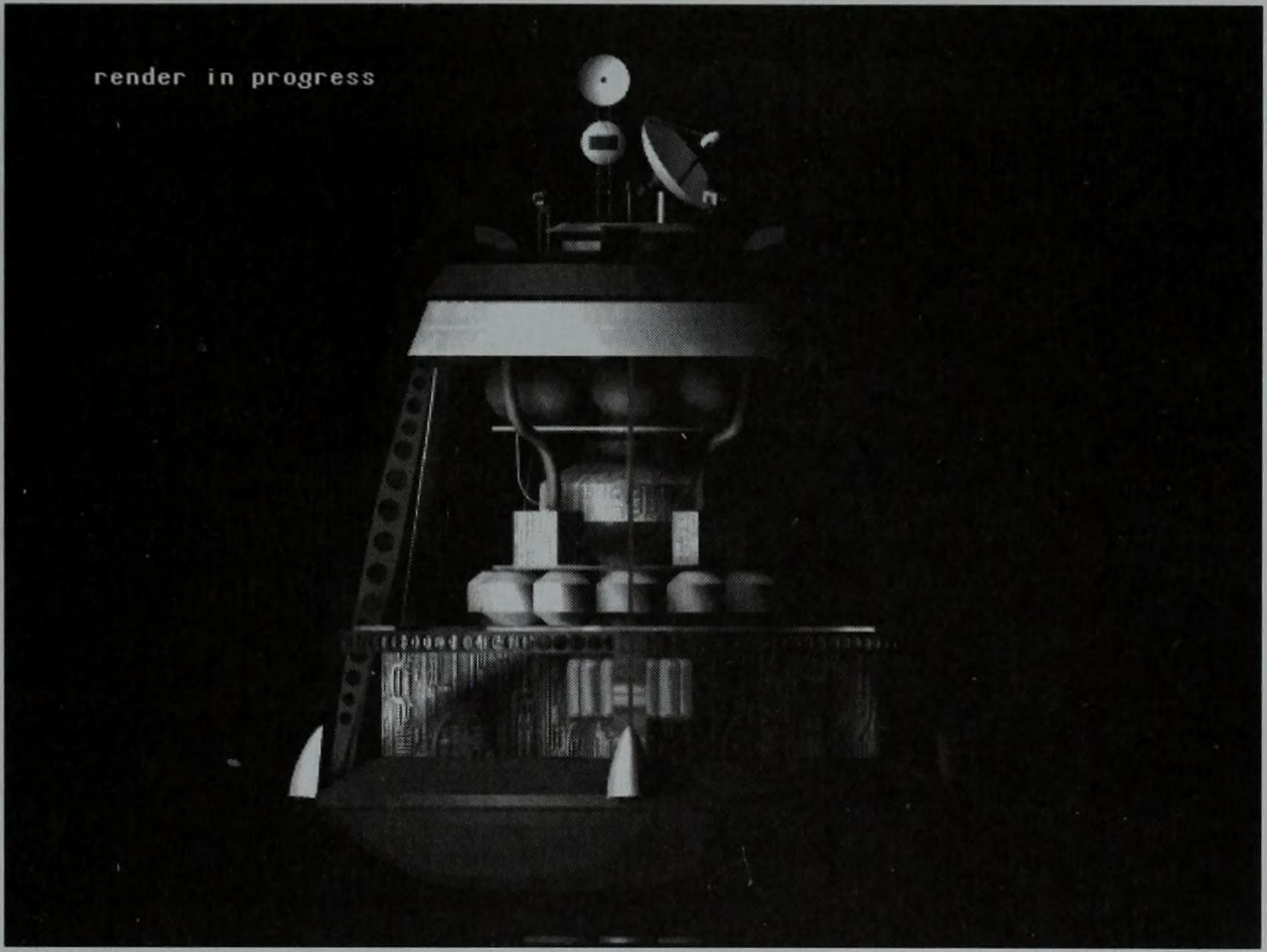


Figure 28-6

Rendered Seed Factory



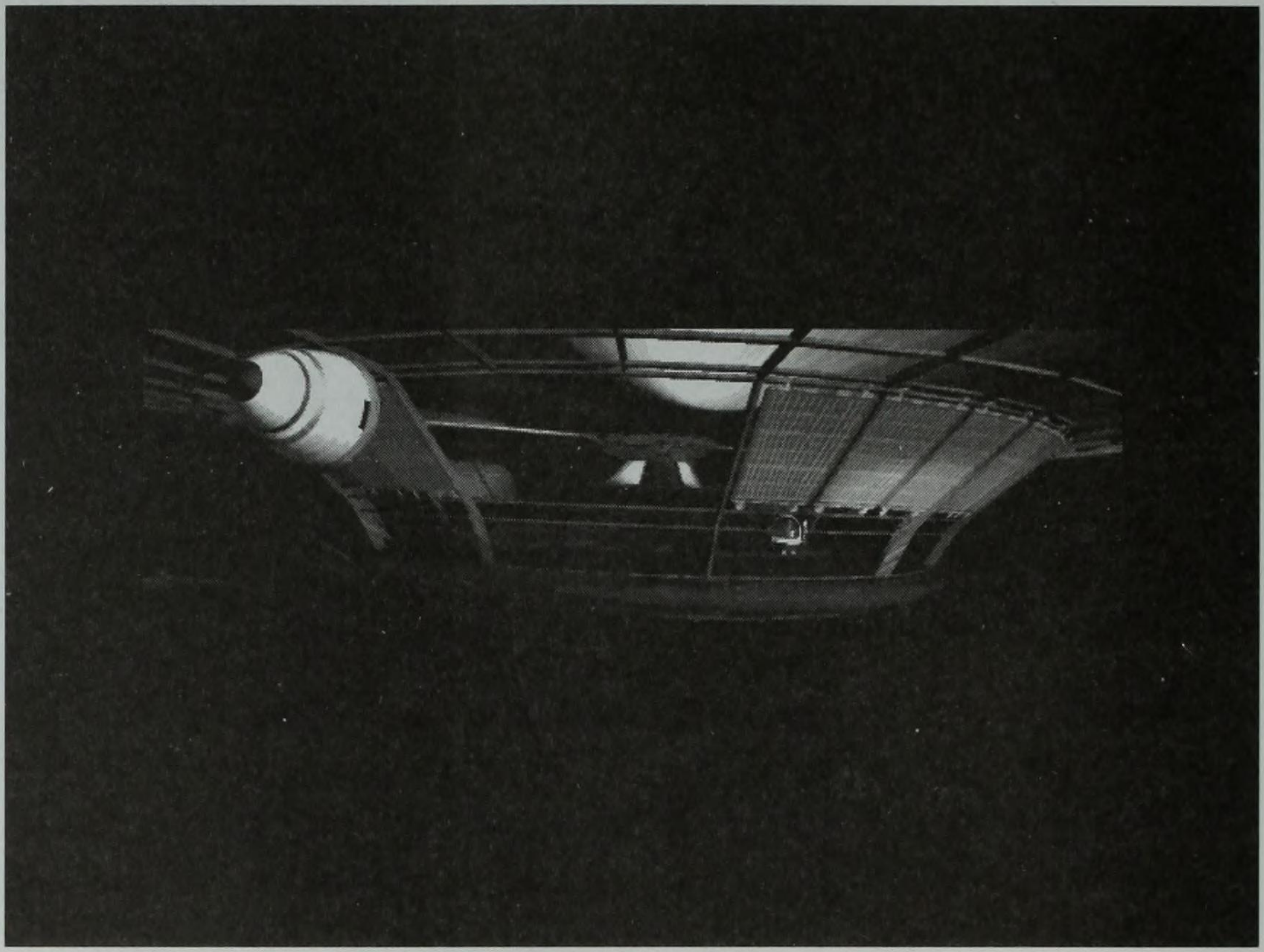
surfaces, such as chrome, and texture maps are used for surfaces such as pitted metal. These maps are drawn from a large library, but the artist can also add new entries to the library. The artist must tell the computer the basic shape to which the texture map will be applied. With these steps completed, and other parameters such as lighting angles and intensities specified, rendering begins. During this process, the computer applies the mapping to the wireframe model and creates a finished image, such as the Seed Factory example shown in Figure 28-6. A rendered close-up section of the starship is shown in Figure 28-7.

For a photorealistic appearance, there is no better method in current use than 3-D rendering. Dedicated high-end systems, such as Silicon Graphics workstations, provide greater speed, a larger image library, and more convenience for the operator, but the technology is the same while the cost is much greater. When you've seen the art in *Outpost*, you know it's the next best thing to being there.

This chapter has given you a quick overview of the 3-D rendered art process used in the making of *Outpost*. The next chapter will give you a terrifying glimpse into the mind of the designer, followed by a disturbing look at the *Outpost* team. If you have a weak heart, or a weak stomach, you'd better stop here.

Figure 28-7

A lander leaves the starship



29

Designer Interview

by Leslie Wilson

Figure 29-1 Game designer at work

[The following interview with Outpost Designer/Producer Bruce Balfour was conducted by Leslie Wilson, the Senior Editor of Interaction *Magazine.]*

Bruce Balfour is rather striking, with brown hair and startling blue eyes that twinkle with mischief. He looks like a Briton; in fact, he descends from the Scots. He is tall, and he slouches.

His sense of humor is understated, and delivered deadpan, so I had to listen carefully. He was a few minutes late for our interview and made no apologies. In this last week of January, Balfour was, in a word, harried.

LW: What in your background, outside of game design, has qualified you to design *Outpost*?

BB: When I was a kid I had pretty bad asthma, so I had plenty of time to read. My favorite authors were Robert Heinlein, Isaac Asimov, Arthur C. Clarke, and Ray Bradbury. Reading them really sparked my interest in space, science fiction, and science. Eventually I started reading science textbooks for pleasure, which for some reason gave people the false impression that I am not a really cool fellow. Anyway, I read a lot of books on space, and decided that when I grew up I either wanted to work for NASA or become a science fiction writer. A third possibility was becoming emperor of the universe, which I still haven't ruled out just because I've done the other two.

LW: You worked at NASA?

BB: Yes, that's kind of an interesting story. One summer when I was getting my computer science degree in artificial intelligence from U. C. Santa Cruz, I decided to do an internship for the experience and some money. I was looking for something out of the ordinary, and I narrowed the choices down to three. There was a computer science position at the Xerox Palo Alto Research Center; there was a position in gamma ray research at McMurdo Sound in Antarctica; and there was a Systems Manager position at NASA-Ames Research Center in Mountain View, California. There really wasn't any contest. The Xerox internship didn't sound interesting enough, and I understand that, even in July, Antarctica can be a little nippy.

LW: What's a Systems Manager at NASA?

BB: You really should use the whole title for where I worked. It was the Space Projects Branch of the Space Sciences Division of NASA-Ames Research Center. It's located at Moffett Field Naval Air Station near San Francisco.

LW: Oh, sorry.

BB: Quite all right, it's a common mistake. Systems Manager is a blanket title, like "Chief Cook and Bottle Washer," or when your job description ends with "all reasonable tasks as assigned by management." I took the internship at the beginning of the summer and it worked out very well. I couldn't believe how much responsibility they gave me. It eventually turned into a permanent position.

Anyway, they had me working on a lot of diverse projects. I worked on one experiment where we intercepted the Space Shuttle on reentry with NASA's Kuiper Airborne Observatory (KAO). The Kuiper Airborne Observatory is a C-141 that carries an infrared telescope in a special chamber. The KAO is normally used for astronomy, and it flies at a high altitude above most of the Earth's water vapor. At the time, you could say it was the world's highest telescope, but now they have some in orbit.

I also did research in artificial intelligence. At the time, NASA wasn't really doing much research into AI, but some of the managers were starting to see the possibilities. My manager, Dr. Henry Lum, was one of them. We were talking about doing things like giving space probes enough intelligence so that they wouldn't require as much control from Earth. I worked on that for a while. In my spare moments, I also headed up the computer center for our part of the network, and managed a small team of programmers…or was that a team of small programmers? It was all so long ago….

LW: Why did you leave?

BB: My life was going too well, so I decided to ruin it. I needed to write full time. I left NASA to write, which I did for 2 years. I sold a few short stories, had three screenplays optioned for production, and I wrote articles for travel, science, and car magazines. And I starved. So, after 2 years I found an interesting job that wouldn't be so taxing that I'd have to stop writing.

I became an engineering test driver for Subaru's test center in Garden Grove, California. I did road and track testing for prototype cars and production models. I'd drive all night, so that the cars were less likely to be photographed by industrial spies, and write for much of the day. Of course, then I wasn't starved for food, I was starved for sleep.

Then an intriguing possibility for employment came up. Interplay, a very small game company at the time, was doing game development for Activision and Electronic Arts. They needed a writer with a science fiction background to help them with the design and writing of *Wasteland*, a computer role-playing game being designed by Mike Stackpole and Liz Danforth. It worked out well for Interplay and me, so I later took on the design of a game based on *The Moon Is a Harsh Mistress* by Robert Heinlein. The plan was to use Interplay's in-house computer language to develop the game for Activision. It was pretty traumatic when Activision killed the project, because I not only designed the game, but wrote and programmed it as well.

LW: Why did Activision kill the project?

BB: They weren't satisfied with the art. Between the time we started the project and the time it was killed, computer art took a big leap forward. Our art was outdated by the time Activision started looking at it. Actually, that's fairly typical of this industry. When you're working with constantly evolving technology, sometimes it moves faster than we do! Anyway, one really wonderful thing happened with *Mistress*. I had the opportunity to talk to Heinlein a few months before he died, and he said he liked my design. That meant a lot to me. And I keep telling people that the shock of seeing my game had nothing to do with his death. Really. It wasn't my fault.

LW: Did you do another game for Interplay?

BB: There were a couple of Electronic Arts deals I spent some time on, but they went nowhere. The next project I completed for them was *Neuromancer*, an adaptation of William Gibson's cyberpunk science fiction novel. At the time, Timothy Leary was handling the computer game rights for Gibson. He was attempting to make a deal with Activision, but they couldn't come to an agreement. When Interplay picked up the project, we visited Leary a couple of times to get his input. Anyway, an Activision producer named Michael Feinberg was really interested in the project, and when the deal fell through he still watched to see what we did with *Neuromancer*.

LW: What did happen with *Neuromancer*?

BB: The deal went to Interplay, and I designed it. Devo did the music. It became something of a cult classic, and went on to win 1989's Best Adventure Game of the Year award from *Computer Gaming World*, which I really appreciated. It also won several international awards.

LW: So you were set as a game developer.

BB: Yes and no. At the time, I saw the potential in this industry for designers who were in on what I perceived to be the ground floor. I also realized that computer game design offered a wonderful opportunity for me to combine my need to write with earning a steady paycheck. Rather than develop and design games independently, I really wanted to be on staff at a progressive organization with a solid future. Sounds like I'm writing a resume.

LW: So you went to work for Interplay?

BB: No. I also did not, under any circumstances, want to stay in Southern California, where Interplay is located. The computer game company I had my eye on was Sierra On-Line, which is located in the Sierra Nevada foothills just 15 miles south of Yosemite National Park. Sierra had always operated with independent designers (Roberta Williams, Al Lowe, Lori Cole, Jim Walls, and Scott Murphy were all independent contractors), but had begun a search for designers to start an in-house development group. In charge of locating designers was Michael Feinberg, the same producer who had worked at Activision and had kept his eye on *Neuromancer*'s progress. When my resume came across his desk, he jumped on it. I was the first game designer hired to work on staff at Sierra On-Line.

LW: What was the interview process like?

BB: It was pretty strange. Feinberg had already decided he wanted to hire me, but I had to pass a few tests. I had to answer all the opening questions from *Leisure Suit Larry 3*, submit to a bad pun contest with then-producer Josh Mandel, discuss the theory of the perfect game design with then-director of development Bill Davis, recall *Space Quest* jokes under the scrutiny of Scott Murphy, eat lunch with Feinberg in a horrible little Chinese restaurant, solve the unified field theory with another producer, and arm wrestle with Ken Williams. It was a tough day and I hope I never have to live through that again.

LW: But you were hired.

BB: Yes, but I didn't know about it for a month. Seemingly in response to my getting hired, the Persian Gulf war got started. I came up here, I guess it was late in 1990, to look for a house to rent. The company put me up at the Best Western hotel in Oakhurst. Feinberg told me Sierra was going to do a mystery adventure game sequel to *The Colonel's Bequest* with Roberta's character, Laura Bow, and he wanted me to show him what my design would look like. The entire design. I had 4 days, in the hotel, to design this game. So, with one eye on CNN news and the other on the Macintosh they lent me to do the job, I created a 100-page design document that was eventually named *The Dagger of Amon Ra*. With some minor modifications, this was the final design document used for *Dagger*, which sold well over 100,000 units. We also made it into a CD-ROM; I directed that project, and met my fiancee while casting voice talent.

LW: What was your next project?

BB: I designed a game dealing with terrorism called *Codename: Phoenix*, for which I used some knowledge I gained at NASA. I also had a consultant on the project who had worked for naval intelligence and the RAND Corporation. Unfortunately, the game would have taken 80 rooms to do it properly, and we couldn't get that large a budget, so the project was put on permanent hold.

At that time, Stuart Moulder, a project manager, wanted to do a strategy simulation game about space colonization and he knew about my background. He was also a *Neuromancer* fan. He approached me about doing the design, and it sounded intriguing. Stuart has subsequently abandoned us and gone over to the ImagiNation Network, our affiliated on-line service, and will probably be in charge of *Outpost*'s conversion to an on-line multiplayer game. After Stuart left, Dan Carver took over management of the project. Dan left for another enormous company that we refer to as the Dark Side, so I became a manager again, and now I'm the designer / producer.

LW: With all that turnover, I assume you're very difficult to manage.

BB: Yes, I am.

LW: How are you as a manager? Does your computer science degree help you deal with your programmers?

BB: I've found that nothing helps with them as much as a whip, a chair, and a piece of raw meat do, but I suppose it does help that I understand what they're doing and how long it takes. One of the challenges to doing a strategy simulation game at an adventure game company is that adventure games generally have large teams of programmers and artists, like I had on *The Dagger of Amon Ra*. *Outpost* couldn't be managed efficiently with big teams.

I like to use artificial intelligence projects as a comparison of a similar complexity to a strategy simulation game. When I was managing an AI project at NASA-Ames, it was impossible for more than two programmers to understand the entire task they had to perform.

LW: Why?

BB: Because AI projects are extremely complex and a lot of communication is required. Everyone has to know what everyone else is doing. Imagine what that would be like with a core team of four programmers and four artists. In its basic form, *Outpost* is really closer to an AI project than to an adventure game.

There are other advantages to a small team: first, we were able to be very selective with who we have on the team. I was lucky to get Dan Brotherton, formerly of Logitech, who is a brilliant C++ and Windows programmer. Second, we only have to depend on a strong core of dedicated employees, and I know where they all live. Third, a dozen doughnuts goes much farther.

The big disadvantage is that there's not a lot of slack. If someone on a small team doesn't do what he's supposed to do, for some reason, it's really difficult for the others to cover.

LW: Are there any other challenges associated with doing a strategy sim at a company that primarily does adventure games?

BB: Sierra has an in-house programming language based on the original Sierra language pioneered by Ken Williams, Mark Hood, and those other guys; its current iteration is called SCI-32. SCI-32 and its predecessors were developed for adventure games. It allows figures to walk around in screens, or "rooms"; objects must either be avoided or manipulated. Each room in an adventure game is relatively independent of the rest of the game. SCI-32 is not set up for Windows.

We are doing object-oriented programming in Microsoft Visual C++ for the Windows operating system, which is an entirely different style of programming. I won't go into detail, but the bottom line is that we have greater flexibility and the game will run much faster than a strategy sim would have in SCI-32.

LW: What is the creative process of designing a game?

BB: It's different depending on the type of game you're designing. When I design an adventure game, I start by telling a story. I bring together a plot, detailed characters, and a conflict. Then I allow for multiple paths through the story. Finally, I add puzzles.

In a simulation, I start with an environment or system that I can model mathematically in a realistic way. That means I have to know almost everything there is to know about each element of the system I'm modeling before I ever begin. Each building in *Outpost*, the fusion reactor for example, functions as a miniature, simplified version of the real thing.

LW: What's the business process of getting a game approved?

BB: It's long, tedious, and may be designed as a protective measure. I'm not sure. The first step is to write a proposal that outlines the type of game and how it's going to be executed. The proposal takes many factors into consideration, including the marketing aspects of the game: target market, an explanation of how it differs from existing games, whether the proposed game will commence a series and how the series would develop, outstanding features that would make people buy it, and the estimated cost of development.

After the proposal is submitted, it's reviewed by Jim Thomas, Sierra's president; Mark Hood, the director of development; and various and sundry marketing people. They evaluate all the proposals they receive, select those deemed viable, and determine whether Sierra has the budget to produce the games. Then an annual schedule is planned.

LW: It sounds like the creative process and the business process rely on two entirely different skill sets.

BB: I think that's true, and it's probably the reason most designers don't manage their own projects. Or maybe they just have more sense than I do. Very often when game players outside the industry find out I'm a game designer, they tell me a great idea they have for a game. The ideas are usually pretty good, and some of them could probably be made into profitable computer games. But if they don't get designed and produced, they'll stay what they are: good ideas.

LW: And yet you do both.

BB: What can I say? I'm an amazing human being with no personal life.

LW: Have you had much involvement in the art?

BB: The team has two very good artists who are both well versed in Autodesk *3-D Studio* software. Of course, when we first got *3-D Studio*, it was a new toy, so I did teach myself how to do some simple structures. I made one of the laboratories used in the game. When I learned the software, I was better able to understand time and scheduling requirements, and the difficulty of certain tasks.

LW: What do you do when you're not designing games?

BB: I write. Last summer, my full length comedy *Gold Rush* was produced for the stage. I spend as much time as possible with my wonderful fiancee.

LW: She's a lucky woman.

BB: Or she's just nuts. After all, she puts up with me and my ridiculous work hours.

LW: What else do you do?

BB: I travel; my lovely fiancee and I will honeymoon in England and Scotland later this year. I hear there are a lot of dead Balfours in Great Britain, and I want to see some crypts. I enjoy skiing and hiking. And, oh yes, I play computer games.

LW: Where do you see the future of computer games?

BB: In the short term, simulations of a variety of real-world tasks and environments. I'm also very particular about the use of the term "artificial intelligence," which has been little more than a buzzword in the computer game industry. I'd like to see real, sophisticated AI built into games, and I'm sure that will happen. Virtual reality, of course, is exciting because it can involve all of your senses and immerse you in the game environment. Interactive movies are, in essence, a higher form of adventure game, and I'm sure we'll see a lot more of that, but right now they're not developed enough to qualify as good games. Pretty pictures are nice, professional voices are nice, good music is nice, but I'd rather watch a real movie or play a real computer game than try to deal with the limited interactions of a computerized "interactive" movie.

LW: What advice would you give to aspiring computer game designers?

BB: I'd say this: there are a lot of bad and mediocre games on the market today. Game design is like writing in that everyone thinks they can do it. They have no idea of the complexity of the design and development process. It's one thing to have an idea for a game, and quite another to write it so that it can be programmed. An additional roadblock is that the market is somewhat glutted with game designers. By this I don't mean that they're all good, but you'd better believe they're out there competing for the job you want. The best advice I could probably give to an aspiring designer is the same advice your mom would give you if you said you wanted to become a movie star.

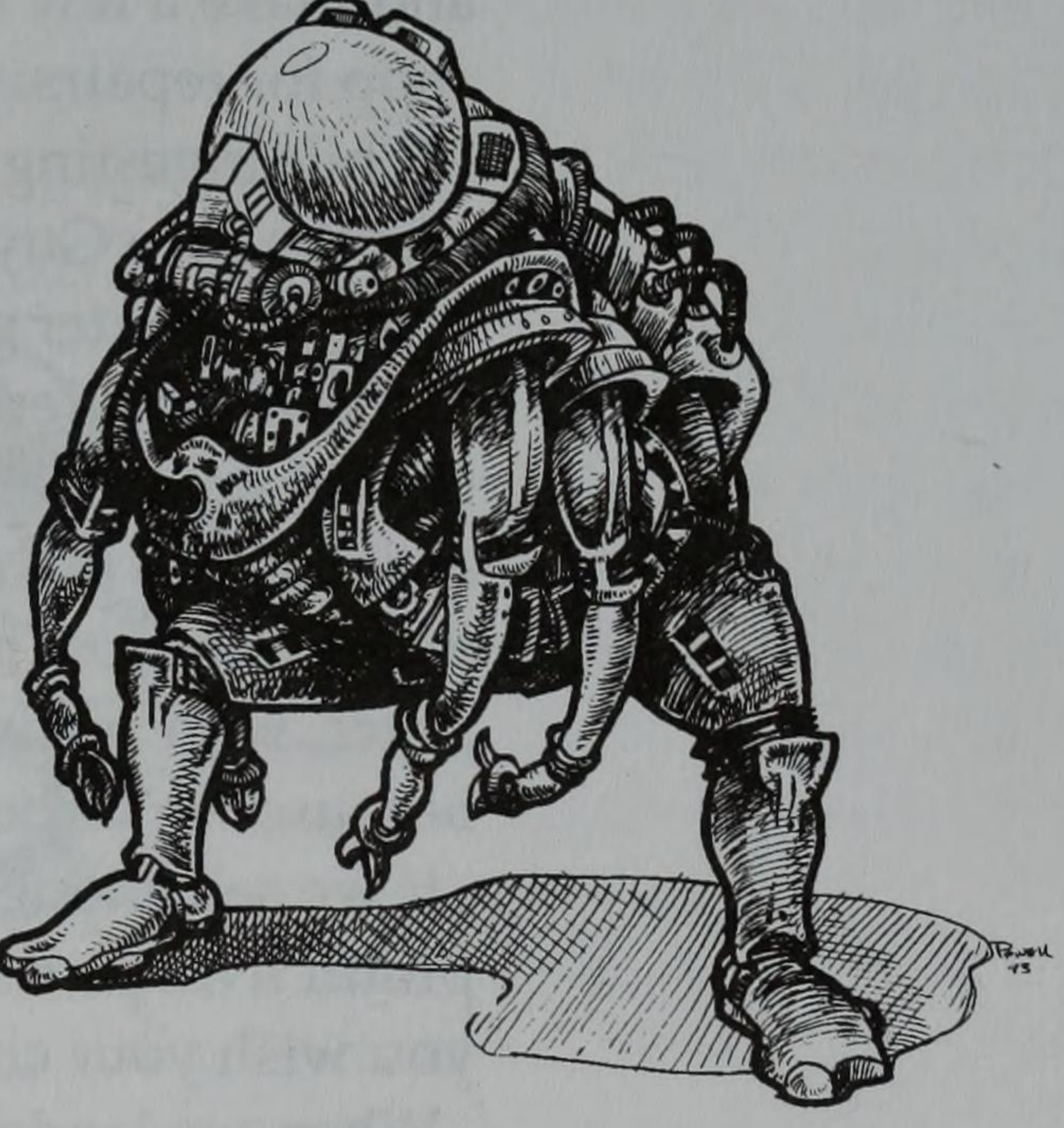
But if there's nothing I can say to discourage you, maybe you're destined to become a computer game designer. Here's some

Figure 29-2

Game designer at home

practical advice. If you can manage it, do a design independently, program it yourself, do your own art or hire someone to do it, add music and sound effects, and then sell it to a game company or get a distributor. If you can't sell it or get a distributor, there's always the shareware route. You can sometimes get started as an independent or staff writer for a game company, often the first step in a career path culminating in game design. A long shot is to become a programmer at a computer game company and to submit proposals when management solicits them. Be ready for heartache and disappointment, and to be forced to "pay your dues." But if you persevere, maybe one day you can join the ranks of the few…the proud…well, you get the idea.

30



Team Profile: The Extraterrestrials from Sigma Draconis III

Stand by to crash.

Herbert Wiley's last command to the crew
of the falling U.S. Navy dirigible, *Akron*,
on April 4, 1933

Figure 30-1 Bud the Bug, *Outpost* team mascot

As I've admitted elsewhere, the *Outpost* team is not composed of humans. If you've ever seen these people eat, you know what I mean. When we were sent to this backwater part of the galaxy to destroy your planet a few of your years ago, our spaceship broke down and stranded us here. We were forced to assume your uncomfortable human forms so that we could fit in with your society, more or less. Since we're a profit-oriented race, we decided to try and make a few bucks off of your planet while our craft is in the shop for repairs.

While ingesting fermented liquids in a stripper bar in Fresno, we met the Two Guys from Andromeda, who suggested that we develop computer games for Sierra On-Line. Our Leader of the Day, "Stuart Moulder," suggested that we make a computer simulation of your backward technology to see if you'd ever leave this mudball of a planet. Seventeen months later, it was finished. When we say *Outpost* is the most realistic space simulation on a computer, with realistic star systems and planets, we know it's true because we've been there.

If we sell enough units of *Outpost*, we may decide to spare your pitiful lives so that we can sell more games. Keep that in mind if you wish your civilization to survive.

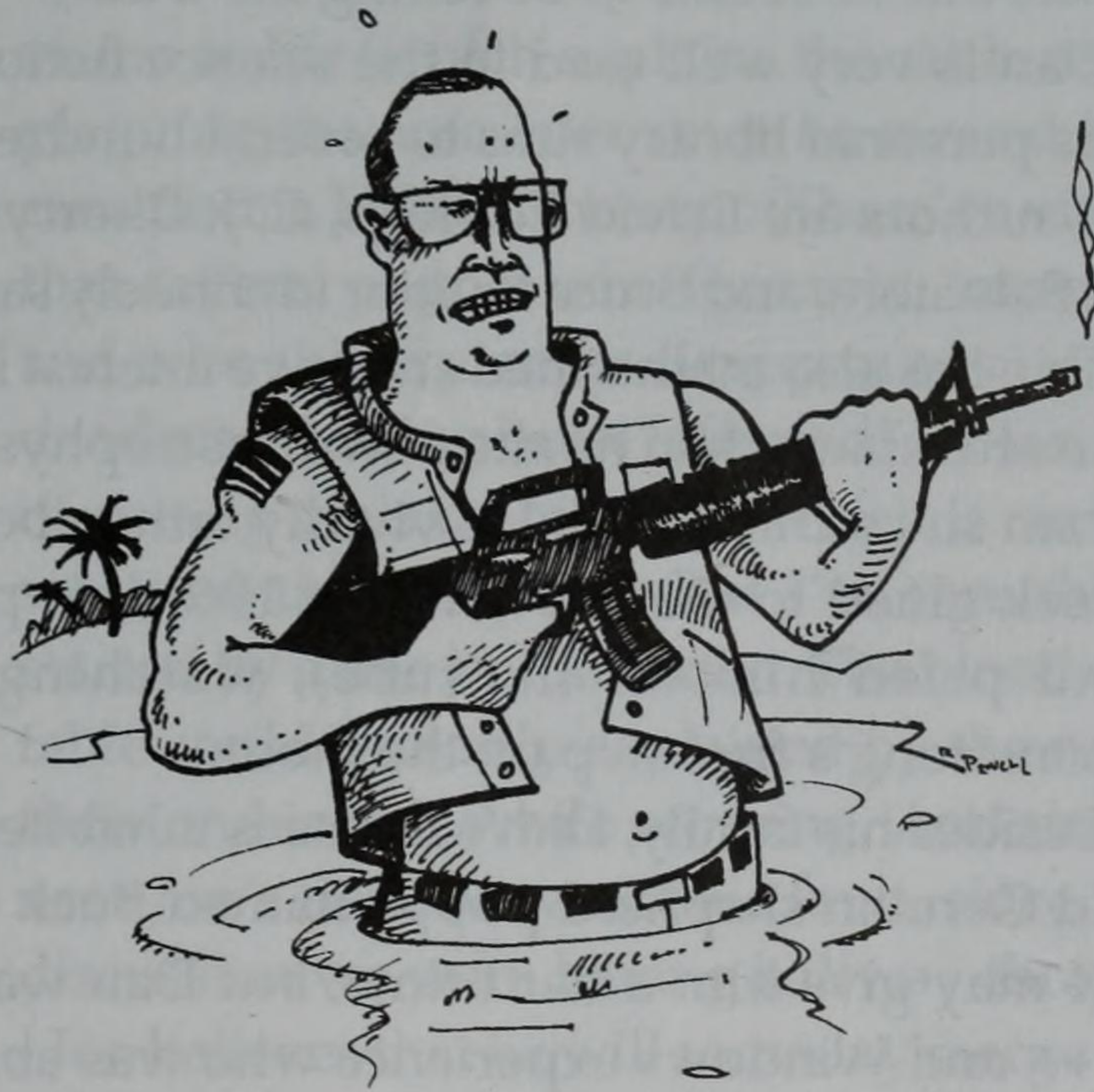
When we landed, I asked my fellow Draconians to prepare fictional biographies that would make them appear more like humans. They have memorized these biographies as if they actually lived on Earth before we started working on *Outpost*. Our artists had the hardest time making their biographies believable, but this can be understood if you remember that their brains are not as highly developed as the scientist class of Draconians. Artists have other advantages, such as extra visual senses specially evolved for handling art tools and ogling female Draconians.

For your amusement, I have included the team biographies in this chapter. These biographies are in their own words, more or less, with my own comments interspersed with their text (and separated with parentheses). You may find some of their writing difficult to read, but it's all part of their charm. They do the best they can, but their brains are often too specialized to perform other complex tasks. We all live around Oakhurst, California, just a few miles from Yosemite National Park, so the thin mountain air also has an effect on their ability to perform mental gymnastics.

Don't Shoot! We're Friendly!

Although there were other contributors to the *Outpost* development process for brief periods, the biographies that follow pertain only to the small core of dedicated individuals that stayed with the project for over a year.

Dan Brotherton (Lead Programmer and Code Master):



Dan is a fourth-generation Californian who comes from a line of pioneers (the Pioneer Class life form is popular on Sigma Draconis III for its advanced brain). Dan's grandfather remembered walking to California behind a covered wagon when New Mexico became too crowded…someone had the audacity to build a house less than 5 miles away.

The year 1975 was a big year for Dan. He discovered both the Burroughs 1700, and Pam White (a human), resident on the campus of Freed-Hardeman University in Tennessee. One discovery led to 17 years of marriage, so far, and to two kids, Chad and Kristi. (Dan did not specify which discovery led to marriage.)

The other discovery (he still didn't specify which one) led to an abortive career in accounting. He got a minor (a small child, presumably) in computer science with his Bachelor of Science degree in accounting. This left him an out when he finally came to his senses.

After coming to the startling discovery that he made a very poor bean counter (farm worker?), he has been pursuing a programming career since 1980 (and we hope he catches it someday). This (poor career move) led to wonderful things like working all night on a regular basis, culminating in spending months of 12- and 14-hour days creating a new development system, as well as a new game, for Sierra (he's referring to *Outpost*). Along the way, he managed to have a lot of fun (he may have said that just to impress the boss, but he seems to be telling the truth).

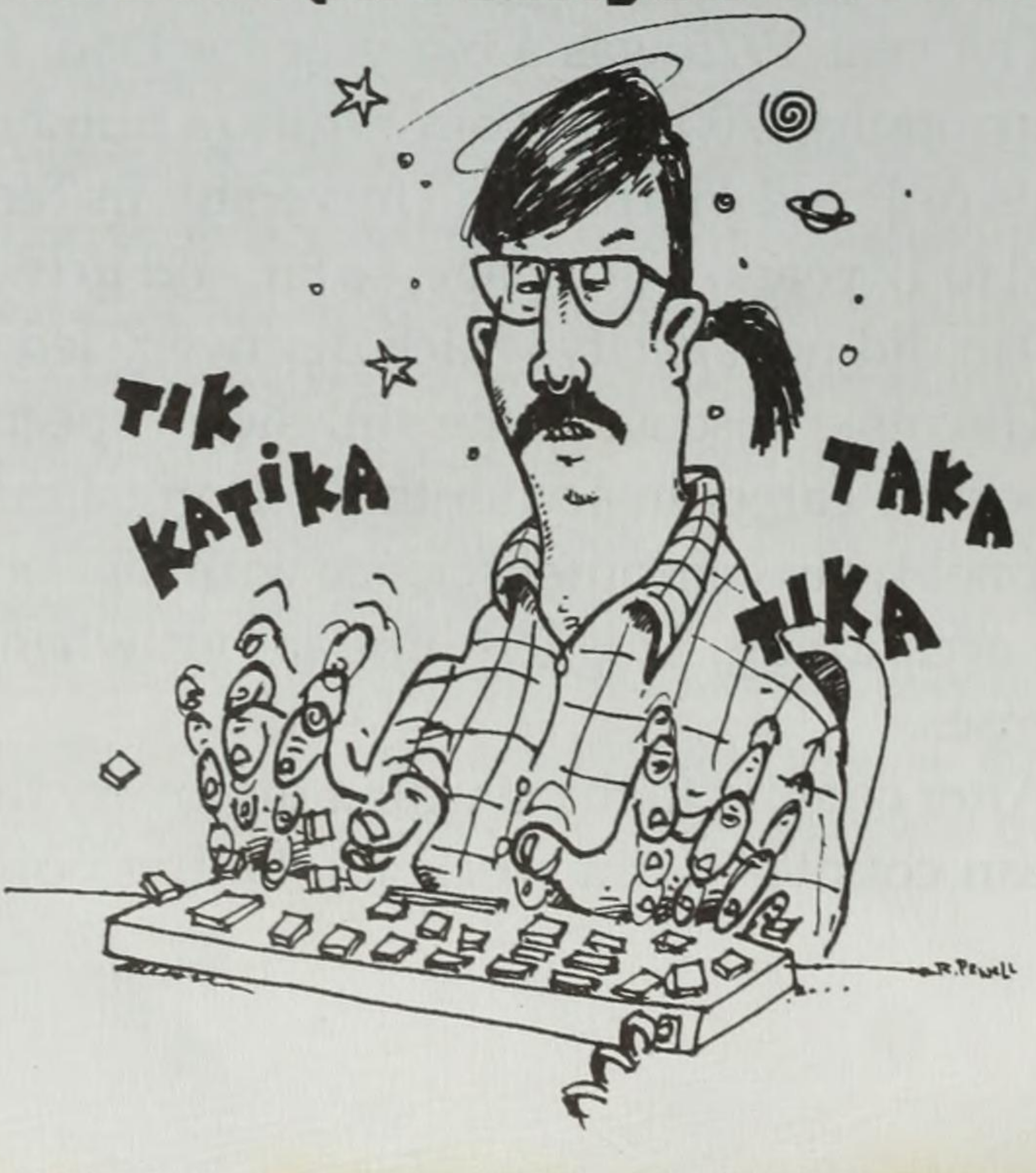
Dan is very well read in the science fiction and fantasy genres. His personal library runs to several hundred volumes. His favorite authors are David Eddings, C. J. Cherryh, Anne McCaffrey, R. A. Salvatore, and Bruce Balfour (definitely said to impress the boss).

Dan has also maintained an active interest in armchair astronomy (he sees stars when he sits down), astrophysics, and the space program since childhood. He vividly remembers spending most of a week glued to the television in 1969 (his parents finally noticed and pried him off the tube), watching *Apollo 11* and Neil Armstrong's first step on the moon.

Besides his family, Dan's house is inhabited by a large, 6-month-old German shepherd puppy named Buck (who kills for sport).

(I may give him a hard time, but Dan was the one with all the C++ and Windows experience who was able to create something from nothing by programming the system and the game from scratch. In his spare time, he trained the other programmers to be fluent in this arcane language. When he arrived at Sierra, Dan thought he was going to work in the Systems Group, but we snagged him before he knew what happened.)

Jon Bock (Art Designer and View Master):



Jon was raised in a plastic bubble (all artists are raised this way on Sigma Draconis III). This gave him lots of time to use his imagination (there was no air inside the bubble, so he was free to hallucinate). Jon has immersed himself in the world of interactive media to such an extent that he refers to washing the dishes as an exciting real-time simulation of domestic duties.

Jon uses any technique available to bring his disturbing inner vision to life (which explains the cattle mutilations that have been plaguing the area ever since he moved here). "If it moves, and I can affect it, I like it," he says. (There's a vicious rumor going around that several people who formerly "moved around" in Oakhurst, and who subsequently disappeared after meeting Jon are, in fact, dead after having been "affected" by Jon. He keeps a wide variety of cutting tools on his desk, which is curious since he does all his work on the computer. But I'm sure this is just an ugly rumor started by some jealous artist. The blood stains under his drawing table could be easily explained by the number of injuries Jon inflicts on himself while working. And the bullet holes in the wall near Jon's desk were not his fault, since they were the result of a discussion we were having halfway through the project.)

Jon believes that he will someday merge into a virtual world from which there is no return. Until then, he plans to create a few of his own.

(After relentlessly pounding art out of Jon for a year, leaving him with numerous broken bones that will never quite heal the same way again, I must say that I've been impressed with the amount of time and effort he puts into his work. Born with a three-button computer mouse in his hand, which he refers to as Elmo, he never seems quite right unless he's staring at a computer screen. I wish you could have been there to see his beady little eyes light up when I introduced him to our spreadsheet program. Every 2 weeks, Jon would pump numbers into his spreadsheet, then watch in amazement as the laser printer spit out the pages with all the neat vertical and horizontal lines. He was so proud of those spreadsheets that he'd make hundreds of copies and pass them out to total strangers in the halls. Tour groups would leave the building knowing the entire schedule for *Outpost* art and commenting on the odd little man in the glasses who accosted them in the hallways.

Jon lives in Ahwahnee, five miles from Oakhurst, in a spooky old hunting cabin of dark wood—you probably saw it in that charming movie, "The Texas Chainsaw Massacre." I drove to his house once, in a pouring rain, on a dirt road that had long since turned to mud, and found my car trapped in a muddy rut half as deep as the Grand Canyon. I know if there hadn't been witnesses around, the same thing would have happened to me that happens to everyone else who drives down that road. I would have had to spend the night in my car, shivering and hoping that Jon wouldn't come out of his house to "help" me.

Everyone at Sierra knows that Jon is going to snap and kill us all one of these days, but we managed to get *Outpost* out the door first. Fortunately for us, he doesn't work for the enemy.)

Randy MacNeill (Code Slave and Engine Room Mechanic):

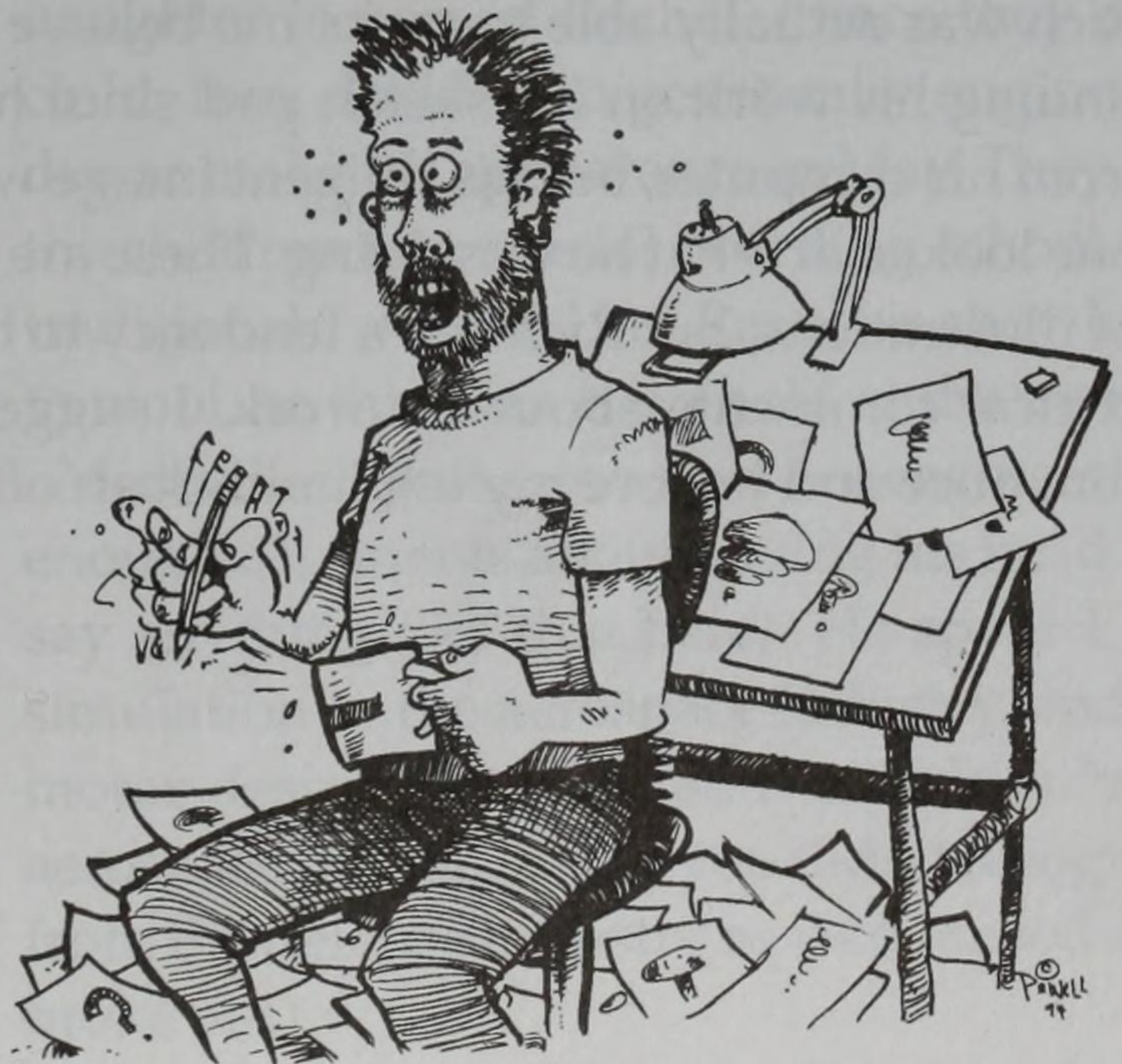
Randy has been married since the end of 1988 to his lovely wife, Wendy, with whom he shares the great joys of his children, 3-year-old Andrew and 1-year-old Rebekah (and they're both as cute as a bug's ear, whatever that means). Randy (who is not as cute as a bug's ear) has worked at Sierra since 1987. (As Randy's family nears the population of a small city, they're expecting yet another bug's ear to arrive in September, 1994.)

(Of all the people on the team, Randy gave me the shortest biography, which probably means something. When questioned about his past by Earth people, Randy usually just stares at them as if he doesn't speak their language, which is true. The only Earth language Randy ever bothered to learn was the programming language, C++.

As modest as he is, Randy doesn't like to talk about his meteoric rise to fame since 1987, when Sierra realized it had a major programming talent sitting in the building. Many of the games that have come out of the high-tech Sierra labs in the last few years bear his mark, and he has been suitably punished each time he has marked a game. The *Outpost* team is fortunate to have him, and we threaten to unleash our artists on anyone who tries to lure him away to another team.

Being something of a low-tech Hittite, Randy doesn't mind using the slowest, steam-powered computer in the building to do his work. His CD-ROM drive, with all of its quaint gears, levers, handcranks, and pulleys made of stone, is a marvel of ancient mechanical engineering. Curators at the Smithsonian keep calling and asking if they can have Randy's computer when he's done with it, but we can't pry it out of Randy's fingers, or toes, to replace it with a new one.)

Rich Powell (Art Guy and Visual Carnivore):



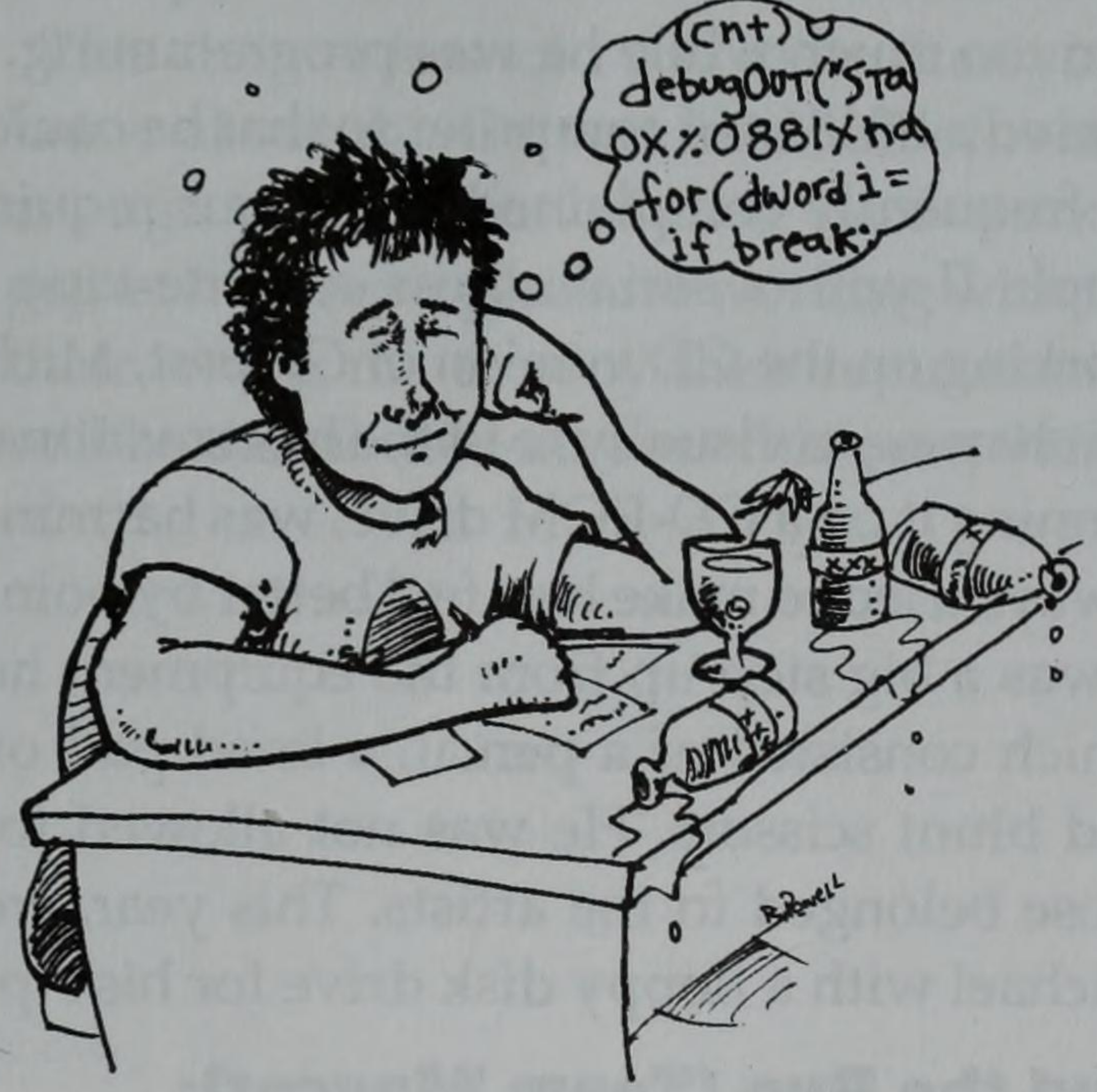
Rich Powell is an ex-Marine cartoonist with a fine arts degree and a steel plate in his head (it's actually a garbage can lid). He got his degree from Cal State Hayward in 1989 and has since gone steadily downhill. His hobbies include frightening people and making spaceship noises. Rich's character design work can be seen in various Sierra games, most recently in *Quest for Glory I* and *III*. His work for *Outpost* permeates the game like the scent of a ripe wheel of goat cheese.

(When I'd finish my daily pounding of art out of Jon, we'd both start in on pounding Rich, because he's bigger than both of us. Rich is always the first person I think of when we need to carry heavy things around the Sierra building, which I'm sure he appreciates. Having grown up in a stronger gravity environment, Rich finds the 1*g* environment of Earth quite amusing.

Rich also gives great Halloween parties at his frightening old house in North Fork, just a few miles from Oakhurst. Rich and his esteemed spouse, Frankie, who is another artist at Sierra, believe that every day should be Halloween and, for them, it is. Rich has a good sense of humor about any subject except Halloween, and displays that sense of humor through the constant stream of words that pour out of him like water flowing over a waterfall. It doesn't even matter if Rich is alone in the room, you could still listen to the wall and hear him telling jokes to himself. As Rich is fond of saying, "It's not easy being me."

Besides his marvelous graphic work on *Outpost*, Rich also did the illustrations you see in this chapter, based on the way he viewed the rest of the team during our regular meetings. For a long time, Rich was actually able to make me believe he was furiously continuing his work on his sketch pad since he'd been forced away from his computer, but his diligent image was blown when someone looked at what he was doing. These are not the most flattering of illustrations, but Rich has a tendency to hurt people who make critical comments about his work. I suggested an art change to him once and he tore my left hand clean off my arm.)

Michael Lytton (Code Slave and Null-Wave Transmitter):



Michael was born in April of 1964 (after which he was raised by wolves—okay, they were actually sheep, but he likes to tell people that they were wolves because it sounds better). Although his birth occurred in Mountain View, California (which probably had an effect on his choice of a programming career later in life), he was raised in Appalachia (by the aforementioned "wolves"). He married his lovely wife, Tricia, in August of 1987. His 3-year-old daughter is named Rachel. (Since they enjoyed having the first child, they decided to genetically engineer a second one, who is due to make his appearance in May. They have discussed sending the children to a special boarding school to be raised by the now traditional "wolves," but Rachel is showing signs of being allergic to wool, so this plan is on hold at the moment.)

Michael's degree is in aerospace engineering (he has already heard enough comments about having his head in the clouds, so I won't say anything like that here). He spent 1 year working on flight simulation in the aerospace industry, and 4 years on solid rocket motor design. They called themselves "rocket scientists" (that's aerospace humor, in case you didn't recognize it). Michael defected from the defense industry as it collapsed all around him (as peace broke out).

Michael loves to fly hang gliders and run long distances (presumably not at the same time). (He says he wants to run a marathon. He doesn't seem to realize he just spent part of a year doing exactly that.)

(Michael has been known to kill for sport, so we tried not to bother him too much while he was programming. Having recently purchased a 80486/66 computer so that he could work faster at home, he frequently complained about our requirement that he use an Apple II with a serial access cassette tape drive at work. While working on the CD version of *Outpost*, Michael often pointed out that having to visually read the information off the CD, rather than running it on a CD-ROM drive, was harming his productivity. We always tried to make him feel better by pointing out that an Apple II was a big step up from the equipment he had to use last year, which consisted of a pencil, a lined pad of paper, library paste, and blunt scissors. He was not allowed to use crayons because those belonged to the artists. This year, we're going to surprise Michael with a floppy disk drive for his Apple II.)

Bud the Bug (Team Mascot):

Bud the Bug was our team mascot, shown in the drawing that started this chapter. At least, we say he's our team mascot. In fact, Bud is what all of our team members looked like before we took on your human forms to blend in better with Earth people. As you can see by Bud's sexy masculine physique, this was not a change we enjoyed making, since our original shapes were so much more utilitarian. In our Draconian bodies, women were all over us when we walked down the synth-streets of our home hives. Now, women on this planet won't even give us a second look. The fact that most of the team members are married to human women does not mean that their wives look at them. As Bud walks around the halls of Sierra, he reminds us of what we once were, and what we will be again after we make a few more *Outpost* games.

Those Other People (not shown):

There are numerous other people who were briefly attached to the *Outpost* team for one reason or another. Mark Seibert and Jay Usher did the music, Victor Sadauskas and Jerry Shaw helped with the programming, Ken Eaton did a bang-up job at hunting down our bugs, Greg Tomko-Pavia dazzled us with physics and relativistic travel calculations, Stuart Moulder got us into trouble in the first place, and Dan Carver stayed with us long enough to offer a variety of useful suggestions since he'd dealt with this sort of game before (we promptly ignored almost all of his suggestions, but we appreciated his enthusiasm and the spirit in which they were offered).

This chapter has told you more than you could possibly want to know about the *Outpost* team, all of whom I respect and admire enough to make fun of their hard work in creating an amazing game. It's been a pleasure working with them all, and I appreciate their letting me destroy their reputations in print in a book that will be distributed all over this puny little planet.

Glossary

aerobraking A technique for slowing the flight of a spacecraft by atmospheric drag. Descent into the upper levels of a target planet's atmosphere causes the craft to slow enough to maintain a stable orbit. The optimum aerobraking maneuver ends before the spacecraft explodes or melts into slag, which is known in technical terms as aerogoofing.

AI The standard abbreviation for artificial intelligence. For a longer definition, see "artificial intelligence."

airbot Airborne robot. If there is no air on the planet where you're trying to use an airbot, this is known as a "pile of junk." In actuality, it's rocket powered, so it doesn't need an atmosphere.

alpha particles Nuclear particles with a positive charge that are ejected at high velocity from specific radioactive transformations. These particles consist of two protons and two neutrons.

Amor Asteroidal objects that cross the orbit of Mars and approach the orbit of Earth. Over short time scales of hundreds or thousands of years, about 10 percent of the Amors have orbits that evolve into Earth-crossing orbits. The first Amor class asteroid was 1221 Amor, discovered in 1932.

Apollo Asteroidal objects that cross the orbit of Earth. The first Apollo class asteroid was 1221 Amor, discovered in 1932.

arc second An arc of 1 second, 1/3600 of a degree of angle, is less than the apparent diameter of a U.S. dime when viewed from a distance of 2 miles, or the apparent diameter of a golf ball when seen from a distance of 5 kilometers, or the apparent diameter of a gnat's eyelash when seen from a distance of…well, you get the idea.

Armageddon A final and conclusive battle between the forces of good and evil. Also a slang term as used in "What's for dinner? Armageddon hungry."

artificial intelligence The goal of artificial intelligence research is to produce computers that can think and learn in a manner analogous to human behavior. This includes the ability to apply known facts, combined with new information, common sense, and guesses to arrive at an appropriate response to a problem.

artificial intelligence personality Your assistant in *Outpost* is a computer with artificial intelligence. It has been provided with an artificial personality to allow easier communication with humans.

asteroid A large interplanetary object that has no characteristic cometary coma or tail. The term includes dormant old comets, covered with dust, that no longer have comas or tails.

astrometry A method for detecting planets in other star systems by watching for periodic changes in a primary star's position due to the presence of a nearby Jovian planet.

Aten Asteroidal objects with orbits that lie mainly inside Earth's orbit. The first Aten class asteroid discovery was 2062 Aten, located in 1976.

AU Astronomical unit. The average distance from the Earth to the Sun, equal to about 92.9 million miles. Also the sound made by someone who drops a star on their foot.

bioengineering The application of engineering principles to biological or medical science. This includes such things as construction of artificial organs.

biosphere The portion of a planet's atmosphere, ground, and water where life can flourish. On a typical planet, the biosphere is located far away from fast food restaurants and used car dealerships.

bioterraforming The use of genetically engineered plant life, such as blue-green algae, to make an Earth-type environment on another world.

black dwarf Superplanets, such as Jupiter or Saturn, that are too far away from their primary star to shine by reflected light, and too small to generate much light of their own.

brown dwarf Planet-like objects with masses up to 85 Jupiter equivalents and cool temperatures in the 120 to 2,000 degrees Kelvin range. The size of a brown dwarf falls between gas giant worlds and small stars. This term was coined by Jill Tarter, a prominent astronomer in SETI research.

calculus of variations I was afraid you were going to look back here for a definition. Okay. You asked for it. This mathematical technique is used to find the optimum path between two fixed-trajectory end points. Typically, this calculation assumes zero initial and final velocities with minimum time trajectories. Propulsion parameters can vary to minimize cruise time and increase fuel costs, or to lengthen cruise time and minimize fuel requirements.

Cambrian The paleontological/geological 100 million-year period that began about 600 million years ago and was characterized by an explosive growth of marine life, primarily the invertebrates and nuclear submarines.

carbonaceous minerals Minerals that are rich in carbon compounds. A carbonaceous chondrite is a class of sooty black asteroid known to be loaded with carbon compounds.

CCD Charge-coupled device. An electronic detector that is several times more sensitive than photographic equipment in capturing images of weak astronomical light sources, such as asteroid movement against background stars.

CHAP Facility Closed Habitat Atmospheric Production Facility, where breathable gases are produced for the colony's contained atmosphere.

chemical fractionation The selection process that determines the composition of an individual planet during its formation.

comet A small body consisting of frozen gases and dust in orbit around the Sun. As it nears the Sun, its surface material vaporizes to form a large head, or coma, at the center of which lies a dark nucleus where its mass is concentrated. In its powdered form, a comet is handy for household cleaning.

comsat Communications and navigation satellite.

constant proper acceleration A term used to describe the throttling down of a rocket engine so as to maintain a constant speed without further acceleration.

constant proper thrust A term used to describe rocket acceleration performed at a constant full throttle, maintaining a uniform fuel consumption rate.

cosmonaut A Russian astronaut.

cryobiology The study of the effects low temperatures have on biological processes.

cryoprotective agents Used to protect cell membranes and organs before freezing. Agents such as glycerol are infused into biological tissues to replace the extracellular water that would expand when frozen.

deorbit A deorbit maneuver drops a spacecraft out of orbit toward the planet's surface.

DIRT Disaster Instant Response Team. The DIRT facility houses this team, which is intended for rapid response to disasters and emergencies in a colony.

drydock A traditional term meaning a dock that can be kept dry during the construction or repair of ships. In space, there's no problem keeping a ship dry, but the drydock has to support a construction and repair crew in the weightless vacuum of their work area.

ecosphere A region in space, near a star, where suitable planets can have surface conditions compatible with the origin, evolution, and continuous existence of land life. Humans can survive the surface conditions on a planet within a stellar ecosphere.

Elevation Map The Site Map screen in *Outpost* can be toggled to show the false-color topographical Elevation Map, indicating the four relative heights of terrain shown on the Site Map.

emergent behavior A biological and philosophical theory used to describe simple systems of interlocking processes that generate unpredictable results of a higher order.

escape velocity The speed that an object must acquire to escape from the gravity of a planet. Also the speed required to outrun a highway patrol car.

false color A method of applying colors to a normal image to make details more apparent.

finishing Part of a fabrication process that refines a basic shape into its final form, as with a finished machine part.

fuel cell A battery cell that continuously changes the chemical energy of a fuel and oxidant to electrical energy. Fuel cells power *Outpost* robots and can be manufactured in your factories.

fumarole A hole in a volcanic region that emits vapors and hot gases, such as steam. This is a very handy sort of hole to find, because you can build a geothermal plant on top of a fumarole to generate power.

gas giant Large, nonterrestrial planets composed primarily of gaseous and liquid hydrogen. In the Solar System, the gas giants are Jupiter, Saturn, Uranus, and Neptune. This type of planet is also called Jovian.

geosynchronous orbit A geostationary orbit. This relates to an artificial satellite that orbits above a planet's equator at the same speed as the planet rotates, so that the satellite effectively stays in the same place relative to the planet surface.

great mambo chicken A tough, powerful type of chicken generated under high-gravity conditions in centrifuge experiments at the University of California, Davis.

greenhouse effect The trapping of infrared radiation by gases in a planet's atmosphere, raising the surface temperature. Also applied to old houses overgrown with climbing vines.

hedgehog Nocturnal insectivorous mammals having both hair and spines that they present outwardly by rolling themselves up. There are no hedgehogs in *Outpost*.

hibernation A slowed metabolic state that allows animals to sleep without food for days or weeks. This is also the state entered by a computer game development team right after it finishes its current project.

hostility level As used in *Outpost*, this is the rating of a planet's relative environmental hostility with regard to humans. As used in computer game development, this is the level of antagonism that the team feels toward the game designer as a project nears completion.

hypoxia Oxygen deficiency in the blood, cells, or tissues. Also the sound of a doctor sneezing.

illuminance As used in *Outpost*, this is the quantity of radiation a planet receives from its primary star. The habitability of a planet depends on this quantity of radiation. It also determines how useful solar powersats will be at a particular planet.

impactors Celestial bodies, such as comets or asteroids, that strike a planetary surface.

infotainment A marketing term used to describe computer game products that have educational as well as entertainment value. This is one of those nightmarish buzzwords that hangs around until people start using it enough that it actually means something.

Jovian See "gas giant."

KAO The Kuiper Airborne Observatory, a civilian C-141 Starlifter aircraft operated by NASA–Ames Research Center. A popular platform for astronomy because it's able to fly above most of the water vapor in the Earth's atmosphere with its infrared telescope. Among its many successes, the KAO was used to discover the rings of Uranus.

kinematics A branch of dynamics that deals with aspects of motion apart from considerations of mass and force.

Kuiper Belt A belt of comets orbiting the Sun just beyond the orbit of Pluto. This comet reservoir was postulated by astronomer Gerard P. Kuiper in 1951 and its existence has been supported by recent discoveries.

lawbot Police robot.

light year The distance over which light can travel during one Earth year, assuming it doesn't use public transportation. Used as a unit to express the distances between stars. One light year equals 0.306 parsec. Ten light years equal one partridge-in-a-peartree. The velocity of light is about 186,000 miles per second.

loose smut A smut disease of grains in which the entire head is transformed into a dusty mass of spores. There isn't any loose smut in *Outpost*, but I was quite amused when I found this term in the dictionary, so I thought I'd include it here just to get your attention.

luminosity A measure of the total radiation emitted by an object: the ratio of the amount of light that would reach us from a star to the amount that would reach us from the Sun if both the star and the Sun were at the same distance from us, which would be a pretty terrifying situation.

macromanagement Strategic management of the overall operations of a complex system, such as a corporation or a colony, without getting involved in the smaller, tactical management issues.

mass driver An electromagnetic rail gun. Used to launch buckets of resources off a planetary surface and into space for use in space manufacturing or as reaction mass for starships.

meteor A flash of light visible as an object passes through a planet's atmosphere and burns up as a result of frictional heating. These objects are no larger than motes of dust.

meteorite A natural object of extraterrestrial origin that survives passage through a planet's atmosphere to strike the planet.

meteoroid A natural object in interplanetary space that is smaller than about 30 feet in diameter. Larger objects are called asteroids.

microbot A very small robot.

MIT Massachusetts Institute of Technology. Also Made In Taiwan and Midget In Training.

mothership See "starship."

nanotechnology The thorough, inexpensive control of the structure of matter based on molecule-by-molecule manipulation; the products and processes of molecular manufacturing.

NEA A near-Earth asteroid passes within the orbit of Mars and approaches Earth. Asteroid 433 Eros, discovered in 1898, was the first NEA to be identified. Amor and Apollo asteroids are both NEA categories.

Oort Cloud The region extending more than 100,000 AU from the Sun, in which perhaps a trillion cometary nuclei are thought to reside. The existence of these shy, but fun-loving, comets was established by an astronomer named Oort, who claims to have met them personally.

optical interferometry An astronomical technique, used in the search for extrasolar planets, that requires widely separated optical telescopes to make use of the interference pattern of light waves coming from closely spaced points in the sky. The greater their baseline, or separation, the better the resolution.

orbital insertion A spacecraft maneuver that places it in a stable orbit around a celestial body, such as a planet.

photolysis The breaking up of a chemical compound by the action of radiant energy, especially light. This form of compound breakup often ends in a messy divorce.

photometry An astronomical technique used to detect variations in a star's luminosity caused by the alignment of a companion between the star and Earth, eclipsing the star.

photosynthesis The formation of organic chemical compounds from water and the carbon dioxide of the air in the tissues of green plants exposed to light. This term can also be applied to the method used by tabloid newspapers to place a photo of one person's head on a photo of another person's body.

planetary ecosynthesis The process of making an Earth-type environment on another world. Also known as terraforming.

planetfall The landing of a spacecraft on a planet. This term also applies to the event of a person tripping and falling on a planet's surface. And there was a pretty good Infocom text adventure with this title several years ago.

powersat Solar power satellite placed in geosynchronous orbit. A powersat uses solar photovoltaic cells to collect a star's energy and convert it to centimeter-length microwaves for power beaming to ground based receiver arrays (rectennas).

primary shaping Part of a fabrication process that involves turning a raw material into the approximate size and shape of an intended machine part. Casting and powder processing are two primary shaping methods that show promise for space manufacturing.

primary star The massive body (a star) around which another body (a planet) is orbiting. This also applies to overweight film stars and their agents.

rad A measure of exposure to ionizing radiation, equal to 100 ergs of energy emitted per gram of absorbing material. This term can also mean "really cool," as in "that movie was rad."

rectenna Solar power receiver array. Receives the centimeter-length microwave power beam generated from an orbital powersat.

refactory Denoting an element or compound that vaporizes at high temperatures, such as uranium, calcium, and aluminum. Also refractory.

regolith The layer of dust and fragmented rocky debris, produced by meteoritic impact, that forms the uppermost surface on planets, satellites, and asteroids.

remote sensing Any technique for investigating an object from a distance. Watching your neighbors through binoculars is a form of remote sensing. Also known as "voyeurism."

repairbot Repair robot. Uses robot spare parts to repair broken robots in the field.

robodigger Robot digger. Creates the underground chambers and tunnels for your colonists so that they can spend most of their time in safety underground.

robodozer Robot bulldozer. Prepares terrain for building structures.

robominer Robot miner. Digs vertical shafts, locates ore, and establishes and operates mines.

Seed Factory An automated, unmanned manufacturing facility. It consists of perhaps 100 tons of the right set of machines, tools, and teleoperated mechanisms to permit both production of useful output and reproduction to make more factories. In *Outpost*, the Seed Factory lands on a new planet to prepare the way for human landings.

self-reproducing automata Machines that reproduce themselves. This idea originated with John von Neumann.

sim Simulation, or simulated life form. The digital inhabitants of a mathematical simulation such as *Outpost* are often called sims. A strategy simulation game may also be called a sim.

Site Map In *Outpost*, this is an orbital view of a landing site on a planetary surface. Some potential mining locations, as well as the locations of your colonies, are indicated on this map.

slow sleep In *Outpost*, the decreased metabolic state of suspended animation in which the colonists travel during their interstellar voyage.

solar flare A sudden, violent release of magnetic energy in or near the Sun's photosphere that often sends great amounts of radiation and highly accelerated charged particles into interplanetary space. Flares are unpredictable, last from a few minutes to an hour, and emit high-energy protons that constitute one of the most serious hazards of spaceflight.

speckle interferometry A mathematical image reconstruction technique that improves optical and infrared images by removing atmospheric interference. At infrared wavelengths, scientists have detected dim companion stars by speckle interferometry.

spectroscopy The study of the light emitted from a body (its spectrum).

SPEW Facility Sewage Processing and Environmental Waste Facility. This is where materials in a colony are recycled.

spysat Spy satellite. The orbital observer satellite performs this function.

starship A generic term for spacecraft capable of making interstellar voyages.

superconductor Various metals that exhibit a complete disappearance of electrical resistance, usually at temperatures near absolute zero.

superplanet A gas giant planet with a history similar to that of Jupiter or Saturn, both of which might be considered small members of the superplanet family.

suspended animation The biological state in which metabolic functions are stopped through deep-freezing, with the intent of reviving the person in the future.

teleoperator A device that allows action or observation at a distant site, by a human operator, through a mechanical or computer interface.

telepresence The ability of a human to sense and affect a remote environment through mechanical means.

terraforming The process of making an Earth-type environment on another world. Also known as planetary ecosynthesis.

Tile Map In *Outpost*, the diamond-shaped terrain map that dominates the main Tile screen. This is where the colony structures are built.

Tile Picker The top center window in the main *Outpost* Tile screen. This is where spacecraft that are available for landing, and structures that are available to build, are displayed.

tokamak The preferred device for generating power from nuclear fusion. The word *tokamak* is the Russian acronym for "toroidal magnetic chamber." The first success of a tokamak device was announced in Moscow in 1968. Also used as a term referring to people who smoke Macintosh computers.

trajectory The flight path of an object, such as a starship, a rocket, or a thrown beer can, through space.

Trojan asteroids Asteroids located near the two stable Lagrangian points of Jupiter's orbit.

ULBI probe Ultra long baseline interferometer.

Valium An antidepressant drug known for its calming effects.

VLBI probe Very long baseline interferometer.

volatiles Elements or compounds with low melting temperatures, such as water, ammonia, potassium, and sodium. It's best not to annoy these volatiles, because they have bad reputations and tend to get into a lot of fights.

vulcanism A general term for the geological processes in which crustal movements are accompanied by the generation of heat and gases, often with the violent ejection of cinders and lava. Also applied to popular sayings attributed to Mr. Spock.

weathersat Weather satellite.

white dwarf A member of a class of small, dense, white-hot stars of low luminosity. These are believed to be composed of collapsed degenerate matter, which is why they are so often found in the sleazy parts of town.

WIMP Weakly interacting massive particle, a hypothetical subatomic particle able to travel freely through matter. Other subatomic particles have a low opinion of the WIMP.

wireframe The basic structural frame of a graphic model intended for three-dimensional rendering.

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